THE AMERICAN SOCIETY OF
HEATING AND VENTILATING ENGINEERS

# TRANSACTIONS

Vol. XXII

TWENTY-SECOND ANNUAL MEETING

New York, January 18-20, 1916

SEMI-ANNUAL MEETING

Detroit, Michigan, July 19-21, 1916

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Meets: *Second Thursday in Month*

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# TRANSACTIONS

OF

# THE AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS

No. 392

## PROCEEDINGS

OF THE

## TWENTY-SECOND ANNUAL MEETING

THE Twenty-second Annual Meeting of THE AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS was held in Engineering Societies' Building, New York City, on January 18, 19 and 20, 1916, under the presidency of D. D. Kimball, New York City; J. J. Blackmore, New York City, officiating as Secretary.

FIRST SESSION—TUESDAY AFTERNOON, JANUARY 18

The meeting was called to order at two p. m., by President Kimball, who said: At this time it gives me very great pleasure to welcome you to this meeting, and to greet you as members of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, at the opening of its Twenty-second Annual Convention.

This should be the best and most helpful meeting we have had, for the reason that the advance in the past year has been greater and more rapid than any other period in the history of the Society. We all hope, I am sure, that there may be as great an advance during the present year. The growth of the Society has been most marked, indeed; we are reaching a growth unthought of by any of us a few years ago. The influence of the Society is also growing in a similar manner. Greater co-operation and interest in us has been shown by other engineering

bodies. Our representation is constantly being sought by other organizations and the progress of our work during the past year has been most encouraging.

Particularly encouraging has been the general participation in the work by our members. I do not think that in any year of the Society's history has there been so much interest in and willingness to work for the general good, as this year has developed among our members. I am sure the spirit would increase if all the members could only realize what their assistance and co-operation mean to the officers of the Society. The co-operation is shown in the value and size of our proceedings, and in the fact that we have published all our Transactions up to date and can, for the first time in our history, state that every volume is issued up to date.

This spirit of co-operation is also shown in the large increase in the membership. In the report that you have before you, it may also be noted that the financial transactions have increased about 50 per cent., and still we show an increased balance of cash on hand.

We are fast approaching, and I believe we shall soon reach, the point toward which we have been striving for a long time, when we shall be able to place our initiation fees in a separate fund for the purposes of research and committee work. Such a fund would be of value to the entire membership of the Society.

Another new feature of our work, about which you all know, is the publication of a quarterly Journal, which enables us to place before you all the papers to be presented at our meetings well in advance of the date of presentation.

We shall be very glad to have letters and discussions sent to the Secretary by the members for presentation in the Journal.

During this meeting, I hope the members will pay particular attention to the rules which we have formed for the purpose of facilitating the work of the sessions.

After the reading of the papers the discussion will be opened by two members, who will have the privilege of the floor for five minutes. After this, other members will have the privilege of the floor, one at a time. A member once having had the privilege of the floor is requested to give way until all others who wish to speak have had an opportunity. The speakers are requested to give their names on rising to take the floor.

We welcome, with the privilege of members, any guests who may be attending this meeting, and I hope that they will use

the privilege of the floor and speak on any subject which may be of interest to them.

The first in the regular order of business is the Report of the Council. The report was read by the President, and on motion, the report was accepted and ordered filed.

PRESIDENT KIMBALL: The next order of business is the Report of the Secretary.

The report was read by Secretary Blackmore, and on motion, was accepted and ordered filed.

PRESIDENT KIMBALL: We will now hear the Report of the Treasurer.

TREASURER ADDAMS: It is unnecessary for me to read a report, as the report is exactly as contained in the report of the Secretary. The only thing of importance is that we show a good balance of cash on hand.

PRESIDENT KIMBALL: You have the report before you, and if there is no objection, it will be accepted and placed on file.

## REPORTS OF COUNCIL, SECRETARY AND TREASURER

### REPORT OF THE COUNCIL

Pursuant to the requirements of the Constitution (Art. VI, Sec. 6), the Council presents the following report of its administration of the affairs of the Society for the past year.

Immediately upon the close of the last annual convention the

FOR THE YEAR 1915

Council met in the office of the Society during the afternoon of January 21st and organized. Following this meeting the usual standing committees were appointed by the President, as follows:

*Executive Committee.*—Frank T. Chapman, Henry C. Meyer, Jr., Homer Addams.

*Finance Committee.*—Frank G. McCann, William M. Kingsbury, Dr. E. Vernon Hill.

*Publication Committee.*—Arthur K. Ohmes, Samuel R. Lewis, Frank G. McCann.

*Membership Committee.*—Frank I. Cooper, Harry M. Hart, James T. J. Mellon.

Mr. J. J. Blackmore was appointed Secretary and has served throughout the year with eminent satisfaction and success. After

the most careful consideration the Council has gradually increased the salary attached to the office of Secretary to $2,100, feeling that the proper conduct of the affairs of the Society in its present size, and the duties added by the publication of the Quarterly, justified this course. As last year, we have been saved the cost of editing the Transactions. It is believed that the results of the year have proven the wisdom of the step taken.

The plan adopted in 1914, of employing a Secretary who should give his entire time to the work of the Society, has proven such an unqualified success that no change in this policy may be properly considered.

Society headquarters have been continued in the United Engineering Society's building, at 29 West 39th Street, New York City, although at an increased rental. This office has been largely used by Committees of the Society and by New York Chapter.

Eleven meetings of the Council, and three meetings of the Executive Committee have been held during the year. So far as possible the views of those members of the Council and Executive Committee who have not been able to attend the meetings have been secured by letter on matters coming before the meetings.

The summer meeting of the Society, originally arranged to be held at San Francisco, was transferred to Atlantic City. It was held September 16th and 17th, and despite the limited notice given to the members, and a somewhat smaller attendance of guests than usual, a most successful convention resulted. Nearly one hundred members and guests attended.

During the year this Society has been represented, by invitation, at the following conventions:

National Fire Protection Association, Boston, by A. M. Feldman, J. A. Donnelly, R. W. Pryor and Frank Irving Cooper; National District Heating Association, Chicago, by E. F. Capron, J. M. Stannard, W. H. Chenoweth, R. L. Gifford and E. A. May; National Warm Air Heating & Ventilating Association, Detroit, by Edward Norris, D. R. Richardson, F. K. Chew, Wm. Ritchie and F. R. Still; American Association of Engineers, Chicago, by S. R. Lewis, H. M. Hart and Dr. E. V. Hill; National Association of Manufacturers, New York, by A. K. Ohmes, J. A. Donnelly and J. J. Blackmore; Pan-American Scientific Congress, Washington, D. C., by R. P. Bolton, delegate, and J. A. Donnelly, alternate.

Our interest and co-operation has been solicited by the New York State Commission on Ventilation, The Chicago Ventilation Commission, The Department of Health and the Building Depart-

ment of New York City, and the Department of Labor of New York State.

That the influence and strength of the Society and the value of membership have been materially enhanced during the last year is assured.

For the first time in the history of the Society the Transactions up to date have been printed and delivered. It is to be hoped that we may not again fall behind in this matter. The increase in the size of the volume of 1915 and the character of the papers therein well merit praise.

The publication of a Year Book has been delayed because of the rapidly changing membership list and because of certain changes in the Constitution which have been suggested. Steps are now being taken to issue such a book immediately upon the close of this convention.

By means of the Journal we have been enabled to place before the members, well in advance of our meetings, all of our papers, and in the most desirable form. For this reason, because of the income received from advertisements, because of the prestige accruing to the Society, and for other reasons that will occur to you, it is believed that the Journal has more than justified its inauguration. It has been the subject of praise from many sources.

An increase of approximately fifty per cent. in the financial transactions of the Society will be observed by reference to the statement of income and expenditures in the Secretary's report, accounted for by increase in membership and the publication of the Journal, with its advertisements.

It will be noted that the Assets of the Society now amount to \$11,001.70, a gain of nearly \$2,000 during the year. However, because of the large increase in the number of members, and the amount paid out on a previous year's Transactions in excess of the amount on this year's Transactions carried over to next year, the net equity per member is slightly decreased, being now \$17.30 as against \$17.92 one year ago.

Despite the extra expenses of administration and the printing of papers and Transactions our cash balance has increased \$184.72 and now amounts to \$2,529.10. Our liabilities have decreased \$1,489.96, now amounting to but \$672.00. Unfortunately the amount of unpaid initiation fees and dues is the largest in the history of the Society, amounting to \$1,598.20, which is \$499.00 greater than last year, and this despite the most energetic efforts of our Secretary. Worse still, the number of members dropped for non-payment of dues this year, as provided by the Constitution,

is greater than ever. Our loss from this has amounted to $640.00.

It has always been our desire to see the expenses of the Society so administered that all of the initiation fees might be put into a reserve fund. How we would have reached this mark this year but for the increase in unpaid dues and the payment of back bills may be indicated by the following table:

| | |
|---|---|
| Increase in cash balance | $166.13 |
| Decrease in liabilities | 1,489.96 |
| Excess of unpaid dues and fees | 499.00 |
| | $2,155.09 |
| Total amount of initiation fees | $1,955.00 |

It is with the greatest satisfaction that we can report that with the per capita costs of the year 1913 and 1914 correctly computed the

TABLE 1. STATUS OF MEMBERSHIP

| | | | | |
|---|---|---|---|---|
| **Honorary members:** | | | | |
| Total number, January 2, 1915 | 2 | | | |
| Accession by election | 1 | | | |
| Total | | | | 3 |
| **Members:** | | | | |
| Total number, January 2, 1915 | | | 435 | |
| Accessions by election | 131 | | | |
| by reinstatement | 5 | | | |
| by advancement from associate | 3 | | | |
| by advancement from junior | 3 | | | |
| | | 142 | | |
| Loss by resignation | 4 | | | |
| by failure to qualify | 5 | | | |
| by non-payment of dues | 24 | | | |
| | | 33 | | |
| Net increase | | | 109 | |
| Total | | | | 544 |
| **Associates:** | | | | |
| Total number, January 2, 1915 | | | 48 | |
| Accessions by election | | 19 | | |
| Loss by resignation | 2 | | | |
| by non-payment of dues | 3 | | | |
| by advancement to full | 2 | | | |
| | | 7 | | |
| Net increase | | | 12 | |
| Total | | | | 60 |
| **Juniors:** | | | | |
| Total number, January 2, 1915 | | | 22 | |
| Accessions by election | | 15 | | |
| Loss by resignation | 2 | | | |
| by non-payment of dues | 3 | | | |
| by advancement to full | 3 | | | |
| | | 8 | | |
| Net increase | | | 7 | |
| | | | | 29 |
| Total | | | | 636 |

per capita cost of this year ($10.59) is less than for several years.

The present membership of the Society and its change during the year are shown in detail in Table 1.

Five ballots for new members were sent out during the year as follows: February 20th, 31 candidates; April 20th, 40 candidates; June 29th, 39 candidates; September 30th, 32 candidates; November 10th, 23 candidates.

The splendid net increase in membership, which is nearly three times that of any former year, has been due to the efforts of many members, ably seconded by our Secretary. The total number of new members elected is 165 and the net increase is 128. It is with regret that we report the dropping of 30 members for non-payment of dues as compared with 16 last year.

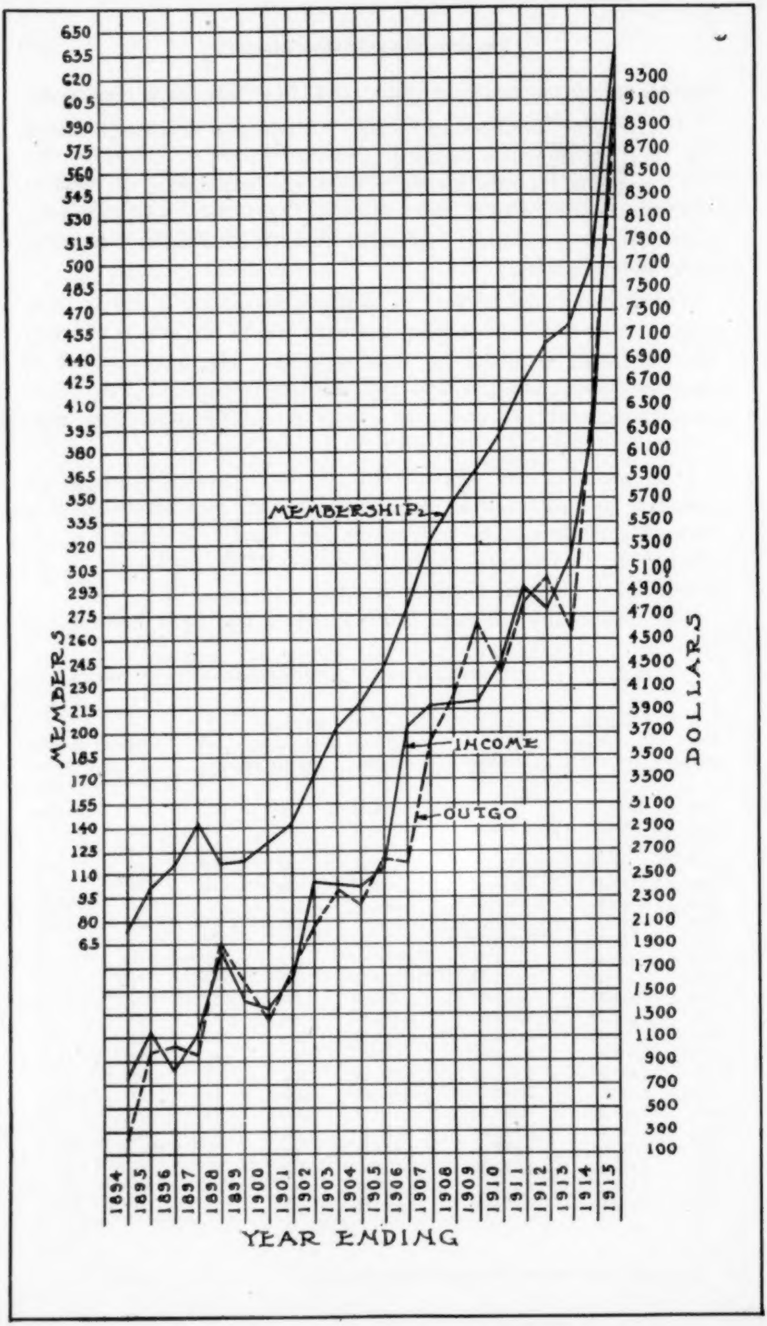
It is with extreme pleasure that we can report the loss of no members by death during this year. Former members who have honorably withdrawn by resignation, are: Harry De Johanis, C. A. Haslett, R. L. Douglas, H. E. Raymond, W. S. Dickinson, V. L. Root, Frank Dobson, Norman A. Hill.

The desirability of each new candidate has been investigated

TABLE 2. YEARLY INCREASES IN MEMBERSHIP AND FINANCES

| Year ending | Cash bal. at end of year | Income | Outgo | Members at close of year | Net increase | Mean No. of membrs. | Expense per membr. based on mean membr. |
|---|---|---|---|---|---|---|---|
| 1894 | $493.18 | $750.00 | $256.82 | 75 | | | |
| 1895 | 373.26 | 1,112.28 | 992.36 | 102 | 27 | 88 | $11.28 |
| 1896 | 176.28 | 845.65 | 1,042.63 | 116 | 14 | 109 | 9.57 |
| 1897 | 327.35 | 1,109.25 | 958.18 | 142 | 26 | 129 | 9.43 |
| 1898 | 305.30 | 1,878.72 | 1,900.77 | 120 | 22 | 153 | 12.42 |
| 1899 | 33.01 | 1,408.09 | 1,680.38 | 121 | 1 | 121 | 13.89 |
| 1900 | 85.93 | 1,327.07 | 1,274.15 | 131 | 10 | 126 | 10.11 |
| 1901 | 80.53 | 1,619.84 | 1,625.24 | 143 | 12 | 137 | 11.86 |
| 1902 | 453.69 | 2,460.34 | 2,086.88 | 174 | 31 | 158 | 13.20 |
| 1903 | 543.49 | 2,423.93 | 2,334.13 | 203 | 29 | 198 | 11.70 |
| 1904 | 684.19 | 2,414.99 | 2,274.20 | 220 | 17 | 211 | 10.78 |
| 1905 | 633.94 | 2,542.75 | 2,593.00 | 243 | 23 | 231 | 11.23 |
| 1906 | 1,794.90 | 3,710.62 | 2,549.66 | 279 | 36 | 261 | 9.76 |
| 1907 | 2,044.86 | 3,912.41 | 3,662.45 | 323 | 44 | 301 | 12.20 |
| 1908 | 1,947.95 | 3,928.93 | 4,025.84 | 347 | 24 | 335 | 12.00 |
| 1909 | 1,212.68 | 3,952.14 | 4,687.41 | 367 | 20 | 357 | 13.13 |
| 1910 | 1,266.95 | 4,324.10 | 4,269.83 | 390 | 23 | 377 | 11.36 |
| 1911 | 1,397.41 | 4,953.54 | 4,823.08 | 425 | 35 | 405 | 11.83 |
| 1912 | 1,041.62 | 4,717.40 | 5,073.19 | 449 | 24 | 437 | 11.47 |
| 1913 | 2,823.20 | 5,272.02 | 4,532.06 | 462 | 13 | 455 | 10.81* |
| 1914 | 2,444.38 | 6,362.49 | 6,487.66 | 507 | 45 | 485 | 11.52* |
| 1915 | 2,629.10 | 9,256.05 | 9,071.33 | 637 | 127 | 571 | 10.59 |
| | | | | | | | Average 11.34 |

*Corrected, according to Secretary's report of 1915.



MEMBERS
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YEAR ENDING

with unusual care and equal care has been exercised by the Membership Committee and the Council in assigning the class of membership to the candidate. That this has been well done, and that the ability and character of the new members has been quite up to those of former years, are evidenced by the fact that not a single candidate has been rejected by the votes of members with whom rests the final decision as to the election or rejection of candidates. Such an experience is unusual.

A bit of retrospection and study of the history and growth of the Society will prove most interesting. The membership increase and yearly gain in financial transactions are closely shown in Table 2 and the chart on page 16.

The rapid acceleration of recent years, and especially of this year is most encouraging.

Applications for charters for two new chapters have recently been received, one at Cleveland, to be known as the Ohio Chapter, and one at Philadelphia, to be known as the Eastern Pennsylvania Chapter. These are splendid indications of the increasing interest in the Society's work.

The President, at the summer convention, suggested that a method of electing members might be devised which would be less cumbersome, less expensive, involve less delay and be more in harmony with the method in vogue in other societies of similar nature. The cost of electing new members this year amounted to $234.25.

The suggestion has been frequently offered that a smaller and more artistic Society badge be secured. It is suggested that this matter be given consideration and that the incoming Council be instructed by the Society as to its wishes in the matter.

Special thanks are due to the members of the Special and local committees who have done so much to make successful the meetings of this year.

Certain new rules have been given in the program for this convention for application to the conduct of the professional sessions in the belief that they will increase the value of, and interest in, the meetings.

Respectfully submitted,

D. D. Kimball, *Chairman.*

New York, Jan. 18th, 1915.

## REPORT OF THE SECRETARY

Volume XXI of the Transactions, which has just been sent to all the members who have paid their dues for 1915, is the largest volume the Society has ever issued and contains six hundred pages.

The printing of Transactions this year amounted to $3,164.54, but the entire cost of Volume XXI was $1,793.95, so that $1,370.59 was paid out on account of previous year's Transactions.

### THE JOURNAL

Early in the year the Council voted to publish a quarterly Journal of the proceedings of the Society, which began with the April number. Three issues have been printed and the cost charged to this year's expenses.

A slight change in the Constitution will have to be made, by adding the words, after the second sentence of first paragraph of Article V: Four dollars of this amount to be considered as the subscription to the Journal. This is to conform with Post Office regulations.

That the members may know the cost involved in publishing the Journal, I give the figures for the three issues and the cost of the papers printed for the last annual meeting as follows:

| | |
|---|---|
| Advance papers | $267.75 |
| April Journal | 158.75 |
| July Journal | 158.98 |
| October Journal | 163.24 |
| | $748.72 |

The advance papers of the year 1914 cost $203.85. The larger number of papers printed in 1915 is shown in the first item. These figures do not include the cost of type-setting, as that is charged to the cost of the volume of Transactions as shown in the balance sheet.

Some extra expense was incurred in the publication of the Journal from that at first proposed as a better quality of paper was used and a standard of one hundred and twenty pages of reading matter was adopted. Two thousand copies were issued of the April number and sixteen hundred of each issue since.

It will be noticed that the Society received $1,108.15 for advertising, and it is hoped that this item will reach two thousand dollars for 1916.

If the membership could be increased to one thousand, the cost of postage on the Journal would be materially reduced.

The receipts for 1915 were $9,256.05 and the disbursements $9,071.33, leaving a surplus for the year of $184.72.

### STATEMENT OF INCOME AND EXPENDITURES

| | | | | |
|---|---|---|---|---|
| Cash on hand, Treasurer's account, January 2, 1915 | | | $2,344.38 | |
| Secretary's contingent account | | | 100.00 | |
| | | | | $2,444.38 |

#### Receipts

| | | | |
|---|---|---|---|
| Dues | | $5,054.30 | |
| Initiation fees | | 2,195.00 | |
| Sale of Transactions, net: | | | |
| Set Vols. 11 to 20 | $37.50 | | |
| Set Vols. 1 to 4 | 30.00 | | |
| Volume 18 | 5.00 | | |
| Volume 19 | 90.00 | | |
| Volume 20 | 102.50 | | |
| Volume 21 | 7.50 | | |
| | | 272.50 | |
| Pin badges | 174.75 | | |
| Sale of Year Book | 6.50 | | |
| Interest on deposits | 37.77 | | |
| Sale of electros | 19.50 | | |
| Sale of reprints | 245.35 | | |
| Excess exchange | .88 | | |
| Sale of papers | 62.20 | | |
| Advertising | 1,108.15 | | |
| Subscriptions to Journal | 24.75 | | |
| Post Office rebate | 54.40 | | |
| | | 1,734.25 | |
| | | | 9,256.05 |
| | | | $11,700.43 |

Disbursements

| | | | |
|---|---|---|---|
| **Transactions:** | | | |
| Vol. 19 printing | $1,100.00 | | |
| Vol. 20 printing (balance) | 750.00 | | |
| Postage and express on Vols. 19 and 20 | 122.34 | | |
| Acct. Vol. 21 printing ............ $882.39 | | | |
| Acct. Vol. 21 cuts ............ 241.56 | | | |
| | 1,123.95 | | |
| Acct. Vol. 22 printing | 68.25 | | |
| | | $3,164.54 | |
| Pin badges | 155.04 | | |
| **Meetings expense:** | | | |
| Advance papers and Journal | 748.72 | | |
| Drawings | 108.00 | | |
| Stenographer (reporting meetings) | 175.00 | | |
| Programs | 33.00 | | |
| Meetings and expenses therewith | 135.25 | | |
| | | 1,355.01 | |
| **General administration:** | | | |
| Salaries | $2,506.00 | | |
| Assessments (rent) of office | 432.70 | | |
| Office stationery, supplies and expen. | 125.57 | | |
| Storage | 45.96 | | |
| General printing | 459.59 | | |
| Ballots | 193.00 | | |
| Telephone | 72.96 | | |
| Exchange | 9.48 | | |
| Postage | 482.31 | | |
| Bonds of Secretary and Treasurer | 7.50 | | |
| Engrossing | 33.50 | | |
| Insurance | 33.60 | | |
| Appropriation, Air Washer Committee | 26.85 | | |
| Attorney | 30.26 | | |
| Returned checks | 42.50 | | |
| Dues, National Fire Protective Asso. | 50.00 | | |
| | | $4,551.78 | 9,071.33 |
| Cash in hands of Secretary (Contingent Acct.) | | | 100.00 |
| Cash in hands of Treasurer | | | 2,529.10 |
| | | | $11,700.43 |

The Society is to be congratulated in having a cash balance on hand of $2,629.10 and a cash surplus over all liabilities of $1,927.03, with a total equity of $11,001.70. This is a gain in total assets of $1,914.28 since last year.

## PER CAPITA COST

Since the report of 1912 the per capita cost has not been accurately computed owing to the fact that a change took place that year in the size of the Transactions.

Your Secretary has reconstructed the per capita table and calculated the per capita cost of the last three years on the same basis as the previous years were calculated but with the actual cost of printing the volume of Transactions that belonged to the year on which the per capita calculation is based.

In the statement of 1913 the cost of transactions is $1,250.02, but the transactions of Volume XVIII, which should have been paid for that year, cost $1,766.21. This would have increased the actual expenses of that year by $516.19, and the expenses of that year would have been as follows:

| | |
|---|---|
| *Statement | $4,400.90 |
| Additional cost of transactions | 516.19 |
| Expenses would have been | 4,917.09 |

Or a per capita of $10.81 as shown in the table.

If the cost of printing a Year Book, that was omitted in 1912, and which would have cost, with postage, $175, be added the per capita would have run up to $11.19.

In 1914, there was paid for transactions a total of $2,246.01, but the actual cost of Volume XX, which was the volume for that year, was $1,410.20, the balance, $835.81, being paid on account of Transactions of previous years. Deducting this and the sale of papers, etc., amounting to $164.40 makes the actual expenses of 1914 equal $5,587.45, or a per capita cost of $11.52.

In 1915, the total disbursements were $9,071.33.

The amount paid for printing transactions in 1915 was $3,164.54. The entire cost of Volume XXI is $1,793.95, the balance ($1,370.59) being paid out on account of previous transactions. We received for advertisements in the Journal $1,108.15, and for papers, reprints, etc., $543.05. Deducting these three items from the total leaves $6,049.54, as the net expenses of the year, resulting in a per capita cost of $10.59.

TABLE OF COST PER MEMBER

| Year | Total receipts | Net cost of operating the Society after deducting expenditures not belonging to that year and deducting commercial transactions. | No. of members at close of year. | New members elected | Net increase for the year | Mean number of members | Expense per member |
|---|---|---|---|---|---|---|---|
| 1907 | $3,912.41 | | 323 | 48 | 44 | 301 | $12.20 |
| 1908 | 3,928.93 | | 347 | 37 | 24 | 335 | 12.00 |
| 1909 | 3,952.14 | | 367 | 54 | 20 | 357 | 13.13 |
| 1910 | 4,324.10 | | 393 | 58 | 23 | 377 | 11.36 |
| 1911 | 4,269.82 | | 425 | 63 | 40 | 405 | 11.83 |
| 1912 | 4,717.40 | | 449 | 54 | 24 | 437 | 11.47 |
| 1913 | 6,160.14 | $4,917.09 | 462 | 57 | 13 | 455 | 10.81* |
| 1914 | 6,362.49 | 5,587.45 | 507 | 80 | 45 | 485 | 11.52 |
| 1915 | 9,071.53 | 6,047.22 | 634 | 165 | 127 | 571 | 10.59 |

The table has been enlarged to make it a complete reference as to the status of the membership. The mean number of members on which the per capita is based is made up by adding one-half the net increase of the membership for the year to the number of members that was on the roll the beginning of the year. That is, there were 507 members on January 1st, 1915, and the net increase was 129; one-half this or 64 added to 507 makes a mean of 571, the theory being that the new members are only carried for a half-year or one-half of them for the full year. This is very conservative, especially this year, as one hundred and ten new members were elected the first half of the year, but that method has been established and it may be well to continue it.

There is every reason to believe that the coming year will see the per capita cost come down to $10.00 per member or less.

That the depression in business circles has been greater in 1915 than in 1914 is evidenced from the fact that thirty members were dropped for non-payment of dues and the amount owing the Society for fees and dues has increased $498.20, the total amount outstanding being $1,598.20.

A new Year Book is in course of preparation and it will be sent to the members in February or March.

The cost of electing members per capita in 1915 was $1.42, as follows: Printing ballots, $193.00; postage, $25; envelopes, $16.25; total, $234.25; divided by 165 members, equals $1.42.

STATUS OF DUES ACCOUNT

Dr.

| | | | |
|---|---|---|---|
| In arrears, including portion of dues of candidates elected December, 1914 (collected $415) | $755.00 | | |
| Paying members, January 2, 1915—504 at $10 | 5,040.00 | | |
| Class of Candidates, Feb. 2—31 at $10 | 310.00 | | |
| Class of Candidates, April 20—40 at $7.50 | 300.00 | | |
| Class of Candidates, June 29—39 at $5.00 | 195.00 | | |
| Class of Candidates, Sept. 30—32 at $5.00 | 160.00 | | |
| Class of Candidates, Nov. 10—13 at $10 | 130.00 | | |
| Reinstated members, back dues | 60.00 | | |
| | | $6,950.00 | |

Cr.

| | | | |
|---|---|---|---|
| Prepayment of 1915 dues in 1914 | $47.00 | | |
| Written off by non-payment of dues | 680.00 | | |
| Written off by failure to qualify | 50.00 | | |
| Total dues received | 5,054.30 | | |
| Difference on account of pro rating dues, account to January 1 | 10.50 | | |
| | | 5,841.80 | |
| Dues outstanding | | | $1,108.20 |

## STATUS OF INITIATION FEES ACCOUNT

**Dr.**

| | | | |
|---|---|---|---|
| In arrears including portion of candidates elected December, 1914 (collected $215) | $345.00 | | |
| Class of Candidates, Feb. 2 | 465.00 | | |
| Class of Candidates, April 20 | 580.00 | | |
| Class of Candidates, June 29 | 555.00 | | |
| Class of Candidates, Sept. 30 | 475.00 | | |
| Class of Candidates, Nov. 10 | 335.00 | | |
| Fee of advancement from junior grade | 15.00 | | |
| | | $2,770.00 | |

**Cr.**

| | | | |
|---|---|---|---|
| Total initiation fees received | $2,195.00 | | |
| Written off by failure to qualify | 85.00 | | |
| | | 2,280.00 | |
| Fees outstanding | | | 490.00 |

**Recapitulation**

| | |
|---|---|
| Total debit accounts of members | $1,598.20 |

## ASSETS

| | | | | |
|---|---|---|---|---|
| Furniture and fixtures | | | $225.00 | |
| Cuts used in printing volumes | | | 250.00 | |
| Stationery and supplies | | | 25.00 | |
| Proceedings | | | | |
| Vol. 1 | 134 | | | |
| Vol. 2 | 9 | | | |
| Vol. 3 | 102 | | | |
| Vol. 4 | 123 | | | |
| Vol. 5 | 96 | | | |
| Vol. 6 | 116 | | | |
| Vol. 7 | 106 | | | |
| Vol. 8 | 82 | | | |
| Vol. 9 | 138 | | | |
| Vol. 10 | 126 | | | |
| Vol. 11 | 142 | | | |
| Vol. 12 | 127 | | | |
| Vol. 13 | 134 | | | |
| Vol. 14 | 136 | | | |
| Vol. 15 | 157 | | | |
| Vol. 16 | 158 | | | |
| Vol. 17 | 186 | | | |
| Vol. 18 | 173 | | | |
| Vol. 19 | 170 | | | |
| Vol. 20 | 245 | | | |
| Vol. 21 | 185 | | | |
| | 2,845 | at $2.50 | 7,112.50 | |
| Accounts receivable | | | 84.00 | |
| Library | | | 400.00 | |
| Membership dues outstanding | $1,108.20 | | | |
| Less uncollectible (estimated) | 220.10 | | | |
| | | | 888.10 | |
| Initiation fees outstanding ($490 less $45) | | | 445.00 | |
| Badges, registration | | | 20.00 | |
| Badges, pin | | | 125.00 | |
| | | | | $9,074.60 |
| Cash on hand | | | | 2,629.10 |
| | | | | $11,703.70 |

LIABILITIES

| | | |
|---|---|---|
| Balance due on Volumes issued to members: | | |
| Vol. 21 | $570.00 | |
| Membership dues prepaid | 47.00 | |
| Acct. of postage and express on Vol. 21 (estimated) | 85.00 | |
| | | $702.00 |
| Membership equity | | $11,001.70 |

The Secretary desires to express his appreciation to those members who have given their assistance in securing new candidates for membership as the increase has been more than double that of any year in the history of the Society, as will be seen by the tabulation, while the quality of the new members ranks high.

The Secretary also desires to express his appreciation to the members of the committees who had charge of the annual and semi-annual meetings, their efforts having resulted in very successful gatherings at each convention.

The influence of the Society has very materially increased during the year as evidenced by the many expressions of interest made to your Secretary by many with whom he has come into contact.

In the year 1916 the Society should secure two hundred new members toward the effort of bringing the membership up to one thousand.

The fact must not be forgotten, however, that the quality of the candidates must be well considered and only those who will bring credit to, and influence for good in, the Society should be solicited in the campaign for new members.

Respectfully submitted,

J. J. BLACKMORE, *Secretary.*

## REPORT OF TREASURER

The Treasurer makes the following report for the fiscal year of 1915, from January 1st to December 31st:

| RECEIPTS | | | DISBURSEMENTS | |
|---|---|---|---|---|
| January: | | | | |
| Balance | | $2,344.38 | | |
| Collections | $1,404.35 | | | |
| Interest | 2.74 | | | |
| | | 1,407.09 | Vouchers | $1,159.69 |
| February: | | | | |
| Collections | | 809.01 | Vouchers | 370.29 |

| RECEIPTS—Continued | | | EXPENDITURES—Continued | | |
|---|---|---|---|---|---|
| **March:** | | | | | |
| Collections ....... | $896.20 | | Vouchers .......... | $1,587.90 | |
| Interest .......... | 9.81 | | Exchange .......... | 1.91 | |
| | | | Returned check..... | 20.00 | |
| | | 906.01 | | | 1,609.81 |
| **April:** | | | | | |
| Collections ....... | | 712.39 | Vouchers .......... | $1,435.79 | |
| | | | Exchange .......... | .73 | |
| | | | | | 1,436.52 |
| **May:** | | | | | |
| Collections ....... | | 607.35 | Vouchers .......... | $559.49 | |
| | | | Exchange .......... | .71 | |
| | | | | | 560.20 |
| **June:** | | | | | |
| Collections ....... | $887.85 | | Vouchers .......... | $481.15 | |
| Interest ......... | 6.63 | | Exchange .......... | 1.11 | |
| | | 894.48 | | | 482.26 |
| **July:** | | | | | |
| Collections ....... | | 230.70 | Vouchers .......... | $294.47 | |
| | | | Exchange .......... | .64 | |
| | | | | | 295.11 |
| **August:** | | | | | |
| Collections ....... | | 908.57 | Vouchers .......... | $782.25 | |
| | | | Exchange .......... | .82 | |
| | | | | | 783.07 |
| **September:** | | | | | |
| Collections ....... | | 335.65 | Vouchers .......... | $273.38 | |
| | | | Exchange .......... | .60 | |
| | | | | | 273.98 |
| **October:** | | | | | |
| Collections ....... | | 352.32 | Vouchers .......... | $563.39 | |
| | | | Exchange .......... | .20 | |
| | | | | | 563.59 |
| **November:** | | | | | |
| Collections ....... | | 1,061.27 | Vouchers .......... | $893.04 | |
| | | | Exchange .......... | .80 | |
| | | | | | 893.84 |
| **December:** | | | | | |
| Collections ....... | $1,010.96 | | Vouchers .......... | $640.51 | |
| Interest .......... | 18.59 | | Exchange .......... | .80 | |
| | | $1,029.55 | | | 641.31 |
| | | $11,598.77 | | | $9,069.67 |

SUMMARY

| | | | | | |
|---|---|---|---|---|---|
| Collections ......... | $9,216.62 | | Vouchers .......... | $9,061.35 | |
| Interest ............ | 37.77 | | Exchange .......... | 8.32 | |
| | | $9,254.39 | | | $9,069.67 |
| Bal. Jan. 1, 1915.. | | 2,344.38 | Bal., Jan. 1, 1916.. | | 2,529.10 |
| | | $11,598.77 | | | $11,598.77 |

Respectfully submitted,

HOMER ADDAMS, *Treasurer.*

PRESIDENT KIMBALL: The next item on the program is a report of the Council relative to the report of the Committee on Ventilation Requirements, which was presented at the last annual meeting and which was accepted subject to some minor changes which were to be approved by the Council.

> The Council begs to report to the Society that the Report of the Committee on Suggestions for Minimum Ventilation Requirements for Public and Semi-Public Buildings for Legislation Purposes as presented in January, 1915, has been carefully considered and after making certain modifications and adding some "Council notations" has been approved and released for reprint and use.
>
> The report will appear in the April copy of the Society Journal, and individual reprints in pamphlet form will be available about February 1st.
>
> FRANK T. CHAPMAN,
> *For the Council.*

PRESIDENT KIMBALL: What is your pleasure regarding this report. If there is no objection, the report will be accepted and ordered on file.

The reports of committees are next in order on the program, but as none of the chairmen are here I shall pass them and proceed to other items until they arrive. The report of the Committee on Cost of Operating Heating (and Ventilating) Plants in Office Buildings will not be made at this meeting. At the request of Mr. Walter S. Timmis, Chairman, it will be laid over until the summer meeting.

I know of no business that would come under the head of unfinished business. If any member present knows of anything in this line I would like to hear from him. Nothing being offered, I shall proceed to the appointment of tellers to count the ballots for officers.

Will Mr. Quay, Mr. Hunt and Mr. Greason serve as tellers?

We will now take up the report of the Educational and Publicity Committee, which Mr. Franklin will present, as Chairman.

The report was read by Mr. Franklin.

The report was discussed by Mr. Chew, Mr. West, Mr. Davis, Mr. Kimball, Prof. Kent, Mr. Lyle and Mr. Franklin. At this point it was voted, on motion of Secretary Blackmore, that the further consideration of the report be deferred to the special session on Thursday morning at 10:30.

PRESIDENT KIMBALL: We shall now have the report of the Committee on Operating Costs of Public Buildings. In the absence of the author, the report was read by Secretary Blackmore.

The report was discussed by Mr. Bolton, and President Kimball.

PRESIDENT KIMBALL: The next paper is the report of the Committee on Cost of Operating Heating and Ventilating Plants in Hospital Buildings.

The report was presented by A. M. Feldman and discussed by Mr. Bolton, Mr. Meyer, Mr. Jas. C. Goodrich and Mr. McCann.

PRESIDENT KIMBALL: Our next business is the nomination of members for the Committee on Nominations for 1917. It is customary to nominate candidates from the floor. I shall ask Mr. Blackmore to record on the board the nominations as given.

S. R. LEWIS: I would suggest that since we have been unfortunate in having had placed on the nominating committee in the past years, men who have already served a number of times, or men who might be available for office, that it might be a good thing if I were permitted to read a list of those who have served recently. I also think that in order that we shall not nominate members who are up for election, that it would be wise for the Secretary to read the present ballot.

The Secretary read the ballot, and Mr. Lewis read the names of members who have recently served.

PRESIDENT KIMBALL: We are now ready to receive nominations for members of the Nominating Committee for 1917.

The following nominations were offered: J. F. Hale, M. L. Foote, Ralph Collamore, Robert W. Pryor, Jr., W. G. Braemer, F. G. McCann, F. K. Davis, W. W. Macon, J. A. Donnelly and W. H. Driscoll.

No further nominations being offered, a ballot was taken. Mr. Kiewitz and Mr. Ehrlich acted as tellers to distribute, collect and count the ballots. Five members were to be voted for.

PRESIDENT KIMBALL: We shall now take up the subject of new business.

S. R. LEWIS: In the course of the development of the Society, it is felt that there are some slight amendments to the Constitution that might be desirable.

The New York Chapter have had a Committee on the Revision of the Constitution, and they have submitted some recommenda-

tions for presentation to the members, and these recommendations have been looked over by the members of the Council.

One is with reference to obtaining information on new members, and in regard to their election. The old way is rather awkward and cumbersome, as well as expensive. We offer the following suggestions for changes in the Constitution:

Article IV, Section 1—Every candidate for admission to the Society, except a candidate for honorary membership, must be proposed by at least two members to whom he should be personally known, and his application must be seconded by two other members. The proposers of a candidate for membership must see that the candidate makes a full and complete statement in writing of his qualifications for membership, including an account of his professional experience and a list of some of his work showing its character and diversity, together with an agreement that he will conform to the requirements of membership if elected.

Art. IV, Sec. 3—All applications for membership are to be sent to the Secretary and they shall be acted upon by the Membership Committee as soon as possible. The names of the candidates passed upon favorably by the Membership Committee shall be printed in the next issue of the Journal or sent to the members in any other approved manner as may be ordered by the Council, accompanied by a notice inviting the members of the Society to submit favorable or unfavorable criticism or information regarding the qualifications of the candidates.

Art. IV, Sec. 4—Following the publication of the names of candidates in the Journal or other publication, as above provided, but in no case less than thirty days after such publication, the council shall vote by sealed letter ballot upon the election of the candidate proposed for membership.

Art. IV, Sec. 5—If favorable votes to the extent of two-thirds of the council shall be cast for a candidate, he shall be elected. The names of the candidates not elected shall neither be recorded nor announced in the Proceedings.

Art. IV, Sec. 6—Those candidates who are elected shall be notified at once, and their names shall be announced at the ensuing meeting of the Society.

Art. IV, Sec. 8 to be omitted.

Art. VII, Sec. 2—Eliminate in the third line the words "Elected by ballot at the annual meeting," and substitute for them "Appointed by the Council within two months after the date upon which it assumes office." Also to change the last word

in the fifth line to "One candidate," and add after the first word in the next line "Each of."

Art. V—Change in constitution. Add after the second sentence of the first paragraph of Art. V: "Four dollars of this amount to be considered as the subscription to the Journal."

These changes are signed by the requisite number to comply with the Constitution and By-Laws.

It is required that these amendments be submitted to a business meeting of the Society, and if accepted by the meeting, the Secretary shall send copies of the proposed amendments to all the members with the reasons why it is thought desirable by the members presenting it that the changes should be made. I move the adoption of these amendments.

PRESIDENT KIMBALL: Are there any remarks, or if not, is the motion seconded.

The motion was seconded and carried that the amendments be accepted and submitted to the Council in the usual way.

PRESIDENT KIMBALL: That was the easiest passage of matters regarding changes in the Constitution that we have had in some time.

We have now reached the point in our program where we shall take up the first of the professional papers, that on Steam Required for Cooking, by Mr. Boyden and others.

The paper was presented by Mr. Boyden and was discussed by Mr. Ehrlich, Mr. Kimball and Mr. Franklin, after which Mr. Boyden replied to the questions raised.

PRESIDENT KIMBALL: We will proceed to consider the next paper by Prof. W. F. Verner, Cost of Removing and Replacing Pavements.

Before this paper is presented, I wish to say, before I forget it, that we have had two applications for charters for new Chapters, one for Eastern Pennsylvania, in Philadelphia, and the other, the Ohio Chapter, in Cleveland, Ohio. The Council has considered these requests and recommends that the Society grant the charters.

There has been nothing more encouraging in the past year than the good work done by the Chapters, for they have all helped materially in advancing the work of the Society.

A motion was made and carried that the charters be granted.

In the absence of Prof. Verner, the paper was presented by the Secretary.

The paper was discussed by Mr. Kimball, Prof. Kent, Mr. Boyden, Mr. Valentine and Mr. Blackmore. The session adjourned at 5.45 p. m.

SECOND SESSION—TUESDAY EVENING, JANUARY 18

The meeting was called to order at 7.50 p. m., President Kimball in the chair.

The tellers made the following report on the election of officers for 1916:

For President—Harry M. Hart, Chicago.

For Vice-President—Frank T. Chapman, New York.

For Second Vice-President—Arthur K. Ohmes, New York.

For Treasurer—Homer Addams, New York.

For Council—Harry M. Hart, Chicago; Frank T. Chapman; Arthur K. Ohmes; Homer Addams; D. D. Kimball; Henry C. Meyer, Jr., New York; Dr. E. V. Hill, Chicago; Frank Irving Cooper, Boston; Walter S. Timmis, New York; C. R. Bishop, North Tonawanda, N. Y.; F. R. Still, Detroit, and M. W. Franklin, East Orange, N. J.

The tellers also made the following report on the election of the Nominating Committee for 1917:

Mr. John F. Hale, Chicago, Ill.

Mr. W. H. Driscoll, Jersey City, N. J.

Mr. R. W. Pryor, Jr., New York.

Mr. W. W. Macon, New York.

Mr. J. A. Donnelly, New York.

PRESIDENT KIMBALL: The first paper to be presented this evening is by Mr. Lewis, Heating and Ventilating Plant, Waite High School.

S. R. LEWIS: This paper was written in accordance with a letter from the Secretary, suggesting that there would be a number of papers outlining the costs of operation of various plants, and asking for one on school-house costs. It is, therefore, more elaborate than might be considered necessary, but it was not intended, when it was written, for a paper to occupy the first pages of the Journal. I do not think that it is necessary for me to read it in detail. I shall simply mention some of the particular points as I go through the paper.

The paper was discussed by Mr. Cassell, Mr. Barwick, Mr. Kimball, Mr. Collamore, Mr. Ehrlich, Mr. Quay, Mr. Kent and Mr. Donnelly and the various questions were answered by Mr. Lewis.

PRESIDENT KIMBALL: The next paper is that of Mr. J. F. Cyphers, The Cost of Heating an Industrial Plant. Mr. Cyphers, is one of our new members and his effort in placing this paper before the Society is, on that account, doubly appreciated.

The paper was presented by Mr. Cyphers and was discussed by Mr. F. K. Davis, Prof. Kent, Mr. Donnelly, Mr. Ehrlich and Mr. Collamore and the questions raised were answered by Mr. Cyphers.

PRESIDENT KIMBALL: The next paper on the program is that of Mr. S. Morgan Bushnell, Cost of Heating the Commonwealth Building of Chicago.

The paper was presented by Mr. Bushnell and was discussed by Mr. Driscoll, Mr. Feldman, Mr. Timmis, Mr. Quay, Mr. Blackmore, and Mr. F. K. Davis and the questions raised were replied to by Mr. Bushnell.

PRESIDENT KIMBALL: The next paper is that of Mr. George W. Martin, Cost of Operating Heating Plants. In the absence of the author, the paper was presented by the Secretary and was discussed by Prof. Kent, Mr. Timmis, Mr. Boyden, Mr. Bushnell, and, as Mr. Martin had sent word he would reply to the various questions raised that they might appear in the Transactions, the matter was referred to the Secretary.

## ׀IIRD SESSION—WEDNESDAY, JANUARY 19

The meeting was called to order at 10.35 a. m., President Kimball in the chair.

PRESIDENT KIMBALL: The first two papers this morning have to do with air leakage, so I think they had both better be read before we enter into any discussion on them.

The first one is Air Leakage Through Windows, by Mr. Henry C. Meyer, Jr., and Mr. S. F. Voorhees.

HENRY C. MEYER, JR.: The purpose of this paper is to give the results of a number of tests on window leakage. The tests were all made by Mr. Voorhees, of the firm of McKenzie, Voorhees and Gmelin, who for some years have been the architects for the New York Telephone Co.

The tests were brought about because of a great deal of trouble and expense in one building where the heating surface was found to be inadequate, due to the excessive leakage around the win-

dows, and a series of tests were run as described in this paper. I do not know that the results of these tests give a correct indication of what might be expected from similar windows. They are correct in a relative sense, however, and serve to bring out the importance of looking into the question of window leakage.

I shall read the paper in full, as it is not very long.

PRESIDENT KIMBALL: The other paper on a similar subject, Report on Air Leakage, by H. W. Whitten and R. C. March, will be read by Mr. Donnelly, whom I have asked to present it, in the absence of Mr. Whitten.

The papers were discussed by Mr. F. K. Davis, Mr. Quay, Mr. Bolton, Mr. Cooper, Mr. Blackmore, Mr. Driscoll and Mr. Ohmes, after which replies to the questions were made by Mr. Meyer and Mr. Voorhees.

PRESIDENT KIMBALL: The next paper, Recirculation of Air in a School, by Prof. G. L. Larson, will be presented by Mr. Ohmes, in the absence of the author.

A. K. OHMES: In this paper there are about forty pages of interesting matter, gotten together in very good shape. As it is impossible to read forty pages in less than one-half hour, I shall just bring out the important points in the paper.

The paper was discussed by Prof. G. C. Whipple, Prof. M. C. Whipple and Mr. Ohmes.

## FOURTH SESSION—WEDNESDAY AFTERNOON, JANUARY 19

The meeting was called to order at 2.20 p. m., President Kimball in the chair.

PRESIDENT KIMBALL: The first paper of the afternoon is that of Mr. Ohmes, on the Testing Institute of Berlin.

A. K. OHMES: My purpose in bringing this paper before you is to make you acquainted with the fact of the existence of this Institute and give you such of its engineering details as I think will interest you. The paper is composed of two parts, first, a description of the building, and then something about its engineering features and experiments. One thing I do not want you to make a mistake about, and that is this data does not cover the complete work done by this Institute, but is merely a presentation of a very small portion of it for the purpose of showing you what has been done.

The paper was discussed by Mr. Feldman, Prof. Allen, Mr. Otis, Mr. J. H. Davis, Mr. Cary and Mr. Driscoll.

At the close of the discussion a motion was offered and carried, that a committee be appointed by the President to consider the advisability of starting such an institute in the United States under the auspices of this Society and to report on the feasibility of such a plan.

President Kimball: The next paper is that of Mr. W. H. Driscoll, A Description of the Heating and Ventilating Plant of the Equitable Building.

The paper was read by Mr. Driscoll, who also offered the following remarks:

Wm. H. Driscoll: I want to preface my paper by stating that whatever success has been obtained in this building reflects credit to Mr. G. W. Hubbard, as he made the original plans for this job and my connection with it was during the course of construction. The tracings and cuts were made under my direction, but are merely a development of the drawings of Mr. Hubbard, in providing for the work of installation. Mr. Henry C. Meyer, Jr., as one of the consulting engineers, is also entitled to considerable credit.

The paper is purely descriptive. I intended to enlarge on it, but found it impossible, so you will find this simply a description of the plant as installed. I shall call this a first of a series of papers going into the various problems and describing the methods of solving them.

The paper was discussed by Mr. Lewis, Mr. Driscoll, Mr. Ehrlich, Mr. Baldwin and Mr. Cary, after which Mr. Driscoll replied to the questions raised.

President Kimball: The next paper is that of Prof. John R. Allen, a very interesting one on the Transmission of Heat in a Warm Air Furnace.

The paper was discussed by Mr. Chew, Mr. Blackmore, Mr. Ehrlich, Mr. Cary and Mr. Baldwin and the questions were replied to by Prof. Allen.

President Kimball: The next paper, the last one of this session, is that of Mr. F. N. Speller, the Prevention of Corrosion in Pipes.

Mr. Speller read the paper and prefaced the reading by the following remarks:

A great deal has been said in recent years regarding the relative corrosion of steel and wrought iron pipe, but little has been done on the prevention of corrosion in pipe. If as much time had been spent toward prevention of corrosion as has been used in vain endeavor to argue the question of relative corrosion, we would probably be much farther ahead and know more about this subject than we do at the present time. I shall read the last paragraph of the paper first, in order to get at the heart of the matter immediately, and then take up the subject in logical order.

The paper was discussed by Mr. Cary, Mr. Carson, Mr. J. H. Davis, Mr. Kinkead and suitable replies were made by Mr. Speller.

### EXTRA SESSION—THURSDAY MORNING, JANUARY 20

The meeting was called to order by President Kimball at 10.45, who stated that this extra session was to consider the report of the Committee on Education and Publicity, of which Mr. M. W. Franklin is chairman. The discussion will be opened by the Chairman of the Commitee, Mr. Franklin.

Mr. Franklin was followed in the discussion by Prof. Kent, Prof. Carpenter, Prof. Allen, Mr. Lewis, Mr. Kimball, Dr. Hill, Mr. Donnelly, Mr. Fuller, Mr. Baldwin, Mr. Hart, Mr. Chapman, Mr. Quay and Mr. West.

A motion to close the discussion was introduced and regularly carried.

It was then moved by Prof. Kent and seconded by Mr. Lewis that the report of the Committee be accepted and that the Committee be continued, and further that the Committee report should be referred to the incoming Council with a request that they co-operate with the Committee in prosecuting this important work in any way that might seem desirable.

The motion was duly put and carried.

### FIFTH SESSION—THURSDAY AFTERNOON, JANUARY 20

The meeting was called to order at 2.15 p. m., President Kimball in the chair.

THE PRESIDENT: I am going to make a slight change in the program by calling for the paper by Mr. J. J. Blackmore on Can We Standardize the Requirements of Ventilation, to be presented first.

The paper was presented by Secretary Blackmore.

President Kimball: The paper is now before you for discussion and the discussion will be opened by Dr. E. V. Hill.

Dr. Hill was followed by Mr. Kimball, Mr. Hart, Prof. Allen, Prof. Kent and Mr. Cooper, and the questions raised were then replied to by Mr. Blackmore.

Chairman Hart: We will now have the report of the Chicago Commission on Ventilation, which will be read by the Secretary.

The Secretary read the report, and it was discussed by Mr. Lewis, Mr. Armagnac, Mr. J. H. Davis, Mr. Baldwin and Mr. Hart.

President Kimball: We will now listen to the Report of the New York State Commission on Ventilation, covering the work done during the year 1915, by George T. Palmer.

The paper was read by Mr. Palmer, who called attention to the cross-arm hanging over the President's chair, which illustrated how the readings of the air movements were made in their experiments.

President Kimball: The discussion will be opened by Mr. Chapman.

F. T. Chapman: I move you, gentlemen, that our Society take this opportunity to send a message to the New York State Commission on Ventilation, expressing our deep interest in and gratification over the thorough scientific research work the Commission is engaged in as evidenced by the paper presented to our Society convention in January, 1915, by D. D. Kimball and Mr. George T. Palmer, entitled Results of Physiological and Psychological Observations During the First Year's Experiments Made by the Commission, and again by the paper presented before us to-day by Mr. George T. Palmer, giving an outline of the activities of the Commission for the year 1915.

The one point of most significant interest to us as Heating and Ventilating Engineers is that the physiological and psychological observations and, in fact, all the research work done by the Commission has tended to prove more conclusively than ever before the need for ventilation in our occupied buildings and that even our quantitative standards of air change established on the old chemical basis serve very well on the new physical one.

The motion was carried.

This paper was further discussed by Mr. Franklin, Dr. Hill, Prof. Kent, Mr. Hart, Mr. McCann, and then Mr. Palmer further explained as to the work of the Committee and answered the several questions raised.

PRESIDENT KIMBALL: We have now concluded our program as far as the professional papers are concerned, and as we have to arrange for a meeting of the Council immediately after this session, I feel under the necessity of dispensing with the customary formality in the installation of the new officers. I trust you will pardon this procedure in view of the circumstances.

I shall have Mr. Hart present himself to the chair and receive the gavel as the badge of his office.

PRESIDENT KIMBALL: Mr. Hart, in welcoming you as my successor, I do so with a great deal of pleasure and satisfaction, knowing that the direction of the affairs of the Society falls into good hands. I do it thinking that you appreciate what the office means, that you know it means more than honor, that it means a great demand on your time and labor, and I am sure that you accept it with that idea. I know that we shall be proud of your work.

Your first duty will be to welcome your associates, and the members of the Council, or rather those of them that are present.

PRESIDENT HART: I wish to thank you for this honor which has been granted to me. I appreciate the fact that there goes with this office much work, as well as honor, but I intend to accept all of the honor that I can get and shoulder all the work I can on others. So now you may know what to expect.

Will Mr. Chapman, the Vice-President, please come forward to assist me. Mr. Chapman came forward and was duly installed.

F. T. CHAPMAN: I thank you for this expression of confidence, and I am pleased to pledge you my best support.

A. K. Ohmes, the second Vice-President, was asked to come forward and was duly installed.

A. K. OHMES: I thank you for the honor conferred upon me, and I can only say that I shall work as well as I did last year.

One thing I want to speak to you about now is the Journal. I should like you to feel a personal responsibility in making the Journal a success. We want the co-operation of all the members to make it a complete organ of the Society. I think you should all submit an article a year to our publication, as this would be one of the best methods of doing something for the Society.

Mr. Addams, the Treasurer-elect, was asked to come forward and was duly installed.

Homer Addams: This is a plain man's job, and needs no further remark.

President Hart: Will the members of the Council please step forward.

The members came forward, and were duly installed by the President, who informed them there would be a meeting of the Council in the offices of the Society on the seventh floor immediately after adjournment of this session.

As there was no further business, the convention was adjourned.

## MEMBERS AND GUESTS PRESENT

### TWENTY-SECOND ANNUAL MEETING, JANUARY, 1916.

New York, January 18-20, 1916.

### MEMBERS

Addams, Homer
Allen, John R.
Armagnac, A. S
Baldwin, Wm. J.
Barr, Geo. W.
Beatty, H. C.
Blackmore, J. J.
Bloom, S. C.
Boeker, Leopold
Boltz, Fred S.
Bolton, R. P.
Boyden, D. S.
Boylston, John
Braemer, W. G.
Brennan, Thos. P.
Burns, Richard D.
Bushnell, S. Morgan
Callahan, M. J.
Carpenter, A. E.
Carpenter, R. C.
Cary, Albert A.
Cassell, J. D.
Chapman, Frank T.
Chenoweth, Wm. H.
Chew, Frank K.
Cooper, Frank I.
Collamore, Ralph
Cyphers, J. F.
Davis, Bert C.
Davis, F. K.
Davis, Jas. H.
Donnelly, Jas. A.
Doherty, P. C.
Dornheim, G. A.
Driscoll, W. H.
Edgar, A. C.
Fabricius, Paul H.
Farnham, George D.
Feldman, A. M.
Fleisher, W. L.
Foote, M. L.
Franklin, Laurence
Franklin, M. W.
Fuller, C. A.
Gardner, S. F.
Goldschmidt, O. E.
Gombers, Henry B.
Goodnow, W. F.
Greason, Samuel L.
Greey, Geo. V.
Hale, John F.
Hall, A. Edson
Hanbury, John F.
Hart, H. M.
Heath, F. R.
Helmer, Louis
Hill, E. V.
Hoffman, Geo. D.
Hunt, Richard B.
Issertell, Henry G.
Jones, Sam
Kent, Wm.
Kiewitz, A. A.
Kiewitz, Conway
Kimball, D. D.
Kingsbury, Wm. M.
Koithan, W. S.
Kottcamp, H. A.
LeCompte, W. G.
Lemmy, Robert
Lennox, F. J.
Lewis, Samuel R.
Lyle, J. I.
McCann, F. G.
McIntire, J. F.
McKiever, Wm. H.
McNair, E. E.
McQuillen, C. B.
Mackay, W. M.
Macon, W. W.
Mallory, H. C.
Mellon, J. T. J.
Meyer, H. C., Jr.
Merritt, Jas. H.
Miller, Max P.
Milliken, Foster
Morrison, Chas.
Murphy, E. T.
Myrick, J. W. H.
O'Hanlon, Geo.
Ohmes, Arthur K.
Olvany, Wm. J.
Otis, James S.
Palmer, George T.
Parter, S. C.
Pearce, C. E.
Pryor, R. W., Jr.
Purcell, A. J.
Quay, D. M.
Ritchie, Wm.
Ritter, Arthur
Sadler, John T.
Sanford, L. Hurd
Schmidt, George G.
Scott, C. E.
Scott, E. A.
Scott, G. M.
Seward, P. H.
Shanklin, J. R.
Speller, F. N.
Sprague, Douglas
Staten, C. H.
Stockwell, W. R.
Stone, E. R.
Strader, B. K.
Teran, C.
Terrell, H. A.
Thomason, L. S.
Timmis, Walter S.
Treat, E. J.
Valentine, F. H.
Wagener, R. N.
Watson, H. R.
Webster, Warren
Weinshank, Theo.
Welsh, H. S.
West, Perry

## GUESTS

Ball, C. A.
Barnum, J.
Barrar, W. G.
Barrett, Jas.
Barwick, Thos.
Beahim, R. B.
Beatty, D. J.
Beverley, W. B.
Bilyen, W. F.
Bookhout, R. C.
Briggs, F. J.
Bromley, C. H.
Campbell, H. D.
Chave, W. E.
Christ, Robt. J.
Coe, Ralph T.
Darss, J. A.
Deuller, E. A.
Dobson, J. B.
Dresbach, H. A.
Eagan, G. A.
Ehrlich, M. W.
Engle, Al
Evans, Norman T.
Finness, D. H.
Fitts, J. L.
Fundinger, C. G.
Garfield, J. B.
Goodrich, Jas. C.
Graham, Joseph
Grassler, E.
Green, Robt. F.
Griere, H. R.
Herzstein, Jos.
Hillman, R. W.
Howard, S. W.
Howes, R. V.
Johnson, A. L.
Jones, Leon
Laurence, Chas. E.
Lewis, R. P. M.
Lyman, C. M.
Lyon, D. T.
Meehan, Jos.
McCormick, J. A.
Meyers, Frank
Munroe, Chas. A.
Mussellman, J. F.
Newman, Howard
Peck, C. B.
Quackenboss, L. H.
Raffin, Edw.
Ressler, M. H.
Ross, A. H.
Sellman, W. T.
Sherman, L. B.
Slocum, C. A.
Stevens, F. H.
Stokes, Harry
Storm, E. S.
Taylor, Wm. E.
Travis, G. T.
VanderVeer, C. P.
VanNostrad, Ben.
Williams, Ernest

## LADIES

Mrs. A. S. Armagnac
Mrs. W. G. Braemer
Mrs. W. W. Browne
Mrs. A. E. Carpenter
Mrs. J. D. Cassell
Miss Esther Cassell
Mrs. B. C. Davis
Mrs. A. C. Edgar
Mrs. M. L. Foote
Mrs. E. V. Hill
Mrs. A. A. Kiewitz
Mrs. W. M. Kingsbury
Mrs. S. R. Lewis
Mrs. F. G. McCann
Mrs. A. K. Ohmes
Miss Ohmes
Mrs. J. S. Otis
Mrs. G. T. Palmer
Mrs. A. J. Purcell
Mrs. Chas. Tebbett
Mrs. B. K. Strader
Mrs. F. H. Valentine
Miss Mildred Welsh

# PAPERS

OF THE

# TWENTY-SECOND ANNUAL MEETING

January 18, 19 and 20, 1916

No. 393

# REPORT OF COMMITTEE ON MINIMUM VENTILATION REQUIREMENTS FOR PUBLIC AND SEMI-PUBLIC BUILDINGS FOR LEGISLATION PURPOSES*

## GENERAL STATEMENT

A correct interpretation of the experimental work which has been carried on, relating to ventilation practice, forces certain conclusions:

A. The necessity for adequate ventilation has been emphasized although the relative importance of certain factors has changed.

B. A high temperature, especially if associated with a high relative humidity, is injurious.

C. The proper relation between air temperature and relative humidity should be emphasized.

D. Air movement in contact with the body materially assists normal heat dissipation.

E. Air supply free from dust, bacteria and other contaminations is important.

We believe that the importance of the following requirements in compulsory ventilation laws have been amply demonstrated:

1. A minimum allotment per person of floor and air space based upon the nature of occupancy.
2. A quantitative minimum air supply requirement.
3. A carbon dioxide test for determining the quantity of air supply and its distribution.
4. A temperature range limitation.
5. The removal from the air of injurious substances arising from manufacturing processes or other causes.
6. Air exhaust requirements for special service rooms (toilets, locker rooms, etc.).

* NOTE.—See General Comments, inserted by the Council of the Society, directly following Committee signatures.

Presented at the Annual Meeting of THE AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, New York, January, 1915.

7. Definite requirements regarding the drawing, filing and approving of plans for both new and existing buildings, in which ventilating equipments are to be installed or changes in the equipment made.

8. Ample authority to enforce the law without recourse to civil action, and with sufficient operative and financial assistance to care for the clerical, field and technical details incurred by such enforcement.

9. The official body charged with the enforcement of such laws shall have authority to promulgate specific rules and regulations covering details of installation and operation not included in the law. Such rules and regulations must not conflict with the full intent and meaning of the law.

Your Committee has decided that it would be impractical to attempt to draft a model ventilation law for reasons herein given, and because this would require an extensive building classification which could not be satisfactorily used in the various states, cities or towns where building laws and regulations, based on other classifications, are now in force. The Committee submits herewith first (under Section I) the specific report covering general suggestions for minimum heating and ventilation requirements that are applicable to all classes of buildings, and second (under Sections II, III and IV) separate sets of more definite requirements for schools and colleges, factories and theatres.

Sections II, III and IV cover three very important classes of buildings, which are often the subject of separate legislation. Many other classes of buildings, such as department stores, hospitals and similar institutions, churches, restaurants, police stations, jails, bakeries, laundries, etc., for which the requirements for heating and ventilation are covered by careful interpretation and use of Section I, would be benefited by separate sets of requirements. It is apparent also that suggestions from our Society, covering practical requirements for the heating and ventilation of street cars and certain other public conveyances are desirable. This report could be considerably enlarged to cover these subjects.

The Committee strongly urges that educational and co-operative methods of improving heating, ventilating and sanitary conditions be studied and used as far as possible in addition to compulsory methods.

The Committee wishes to thank the various members of the Society and others who have assisted in any way in the compilation of these recommendations. Whenever asked for, information was

cheerfully given when such information was available. Acknowledgments are especially due the investigations and recent committee reports concerning the work in New York City and to the ventilation code and experience in the City of Chicago.

James D. Hoffman, *Chairman*
E. Vernon Hill
Frank T. Chapman

GENERAL NOTES INSERTED BY THE COUNCIL

Our Society has, from time to time, been asked by State and legislative bodies and by public health and other organizations to furnish suggestions that will be of value in drawing up legislation regarding the heating and ventilation of buildings and this Committee report presents general suggestions intended to be both conservative and practical.

Attention is called to the fact that the Committee report deals with old buildings as well as new. The City of Chicago makes its ventilation laws apply to both old and new buildings with good results, yet there are some who object to making legal requirements apply to buildings other than new buildings. If in any case the following suggestions are used to apply to new buildings only, some modified requirements, as near the requirements for new buildings as possible, should, in the interest of public health, be enforced for existing buildings.

The subject of ventilation embraces many variable factors (especially in the case of factory work rooms) and the Committee has made its suggestions cover the general features in heating and ventilation most essential to the public health and decency in such a manner as to reasonably well protect the public with the least possible requirement for equipment; and has suggested practical conditions that should be maintained without unnecessarily limiting the method of obtaining the results.

It is often desirable to have humidifying apparatus and humidity control, but, because of the expense of such equipment, humidity control (except as to keeping down excessive humidity) has been omitted from the suggested requirements.

It is important to note that the suggestions given in the report are for average localities in the United States, taking New York, Boston and Chicago as examples, and that some modifications may be desirable to suit localities like the Pacific Coast, Gulf States and Alaska, or localities of unusually high altitude and dry climates

Specific rules, not included herein, will be needed covering details of installation and operation, such, for example, as have been formulated and adopted with excellent results by the Department of Health in the City of Chicago and the Industrial Commission of the State of Wisconsin.

The removal from work rooms of objectionable dusts, fumes, gases, vapors, odors, fibres and other impurities created in manufacturing processes, covered by general requirements in the report, is vitally important and will require specific rules that are practical and that may be widely applied. Space conditions per occupant should, under these conditions, be most liberal. Some good rules for removal of dusts, etc., from manufacturing establishments have been drawn up by the 1915 Industrial Board of the New York State Department of Labor and by the Industrial Commission of Wisconsin.

The administrative features of enforcing general ventilation laws are extremely important, and experienced and capable engineers are necessary as inspectors and as advisors to the administrative department.

Good laws are often made almost useless for the want of proper administration and likewise inadequate laws are sometimes largely compensated by efficient and wise administration.

THE COUNCIL.

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## SECTION I

## GENERAL SUGGESTIONS FOR THE COMPILATION OF LAWS FOR COMPULSORY VENTILATION

(Applicable to all Classes of Buildings)

*General*: Sufficient and proper heating and ventilation shall be provided and maintained during occupancy in all rooms and all enclosed spaces, in all classes of buildings, to insure reasonable health and comfort conditions and maintain the requirements of Articles I to X inclusive.

*Article I—Space per Occupant (minimum requirement)*

| | |
|---|---|
| Schools and colleges—class, study, lecture and recitation rooms, floor area per occupant in sq. ft. | 15 |
| Schools and colleges—class, study, lecture and recitation rooms, space per occupant (volume divided by number of persons) in cu. ft. | 180 |

| | |
|---|---|
| Primary schools—class and study rooms (pupils under 8 years of age), floor area per occupant in sq. ft......... | 12.5 |
| Primary schools—class and study rooms (pupils under 8 years of age), space per occupant in cu. ft........... | 150 |
| Theatres, auditoriums and court rooms, floor area per occupant in sq. ft.................................... | 6 |
| Theatres, auditoriums and court rooms, space per occupant in cu. ft........................................ | 90 |
| Factories, manual training rooms and other work rooms, space per occupant in cu. ft......................... | 250 |

Minimum space conditions in all classes of buildings or rooms not tabulated shall be reasonable and practical and shall meet the approval of the Department of Health.

*Article II—Air Supply (minimum requirement)*

Sufficient outdoor air shall be provided for all occupied rooms or enclosed spaces at all times during occupancy, as may be necessary to meet the requirements of Articles I to XI, inclusive.

The supply of outdoor air for the following classes of rooms shall be positive and based on a minimum quantity of air per occupant per hour as tabulated:

| | |
|---|---|
| Class, study and recitation rooms in all schools and colleges, cu. ft. per occupant per hr......................... | 1800 |
| Theatres, court rooms and other auditoriums............ | 1200 |
| Factories, manual training rooms and other work rooms... | 1500 |

All air supply for ventilation must be from an uncontaminated source or air from which the dust or other impurities shall be sufficiently removed by washing, or otherwise, subject to the approval of the Department of Health.

*Article III—Air Distribution*

The distribution and temperature of the air supply for ventilation shall be so arranged as to maintain the temperature requirement, as stated in Article IV, without uncomfortable drafts, or any direct draft lower than 60° F., and as a test of proper air supply and distribution, it shall be required that the $CO_2$ content shall not at any time exceed 10 parts in each 10,000 parts of air based upon tests of air samples taken in a zone from 3 to 6 ft. above the floor line in any part of the occupied spaces. This requirement may be modified by the Department of Health, or other properly constituted authority as applying to breweries, water charging rooms or

other rooms where carbon dioxide is liberated in manufacturing processes.

*NOTE.—While carbon dioxide in the air, in reasonable quantities, is not considered injurious to health, its presence in occupied rooms is an accurate measure of the air supply and distribution, if no other source of carbon dioxide is present except the occupants of the room.*

*Article IV—Temperatures.*

The temperature of the air in occupied rooms in all classes of buildings, during the periods of occupancy, shall be not less than 60° F., nor more than 72° F., except when the outside temperature is sufficiently high that artificial heating in the building is not required. This requirement shall not apply to foundries, boiler or engine rooms, or special rooms in which other temperatures are required or considered advisable as approved by the Department of Health.

*Article V—Heat Sources*

Any heat source which does not contaminate the air and which does not conflict with the requirements of the Health, Fire, Building or Electrical Departments may be used both to warm the air supply for ventilation and to provide heat by direct radiation.

*Article VI—Removal of Injurious Substances by Mechanical Exhaust or Other Practical and Positive Means.*

Where dust, fumes, gases, vapors, odors, fibres or other impurities are created or released in the course of a business or process carried on in any work room or other place in quantities tending to injure the health of occupants, there shall be provided canopies, hoods or other special devices, connected with an exhaust fan or fans of sufficient capacity and operated at sufficient pressure to remove such impurities at their point of origin. Such fans shall be kept running constantly while such impurities are being generated or released and shall discharge through ducts or flues to a point above the roof or otherwise, and when so directed by the Department of Health be provided with dust collectors or separators as may be required to safeguard the fresh air supply of the building or adjacent buildings and prevent any public nuisance. If practical and positive means, other than mechanical exhaust, can be devised for keeping these impurities from the air, such means may be used when formally approved by the Department of Health.

### *Article VII—Excessive Temperature and Humidity*

If, owing to the nature of the work done or the process carried on in a work room, factory, or other place of employment or occupancy, excessive heat or humidity is caused therein sufficient to be injurious to health, there shall be provided and maintained special means or appliances to reduce and control such excessive heat and humidity as may be ordered by the Department of Health.

### *Article VIII—Special Service Rooms*

Public and semi-public locker rooms, coat rooms, dressing rooms and wash rooms shall have exhaust ventilation equal to not less than six changes of air per hour, except where the window area opening directly to the outside air equals or exceeds one-eighth of the floor area of the room, subject to the discretion of the Department of Health.

### *Article IX—Toilet Room Ventilation*

#### (*a*)—*Installations in New Buildings*

Every toilet room or every water closet or urinal compartment shall be ventilated directly to the outer air by a movable window or by skylight with fixed or pivoted louvres. Every such room or compartment shall have a window or glass skylight not less than one foot wide and of an area of at least six square feet for one water closet or urinal. For every such additional fixture the area of the window or skylight shall be increased by at least one square foot. The Department of Health may require mechanical ventilation in addition to the above requirement where under any special conditions, the window ventilation is deemed inadequate. The Department of Health may permit the installation of toilet rooms, water closet or urinal compartments with less window or skylight area than specified in this paragraph above, or without direct connection to the outer air, if a mechanical system of exhaust ventilation is provided, maintained and continually operated. This mechanical system shall consist of metal or smooth masonry ducts from the individual toilet rooms or compartments, to a fan or fans of sufficient capacity to exhaust a volume of not less than thirty-five cubic feet of air per minute for each water closet or urinal. If the air is exhausted from within two feet of each fixture this amount may be reduced to twenty-five cubic feet of air exhausted per minute per fixture, but in no case shall less than six changes of air per hour be allowed.

*(b)—New and Existing Equipments in Old Buildings*

In existing buildings erected prior to the passage of this ordinance, every toilet room or water closet or urinal compartment shall be ventilated to the outer air by movable window, glass skylight with fixed or movable louvres, or by ventilating duct. Whenever any such toilet room having more than two fixtures (water closets or urinals) is ventilated solely by ducts, or whenever the window or skylight area is one-third less than the area required for "new buildings" positive ventilation complying with the requirements of subdivision (a) of this Article IX shall be installed and maintained if so ordered by the Department of Health. The Department of Health may, at its discretion, modify this requirement for four or less fixtures, or may require ventilation for two or less fixtures.

*(c)—All Installations*

Every window or skylight mentioned in (a) and (b) of this Article shall be so constructed and maintained as to be easily opened at least one-half of its required area for windows and one-fourth its area for skylights. All exhaust fans used for ventilating toilet rooms shall exhaust to the outer air above the roof or at such points as not to cause offense to the occupants of the building or any other building or to create any public nuisance in the neighborhood.

*(d)—Air Shafts*

Whenever any air shaft used for ventilating toilet rooms is covered by a skylight, the net opening or openings available in such skylight shall be at least equal in area to the cross-sectional area of the shaft requirement.

*Article X—Cellars*

All cellars, basements or spaces beneath buildings of any class or character shall be provided with windows or other means of ventilation and such cellars or spaces shall be at all times properly ventilated and maintained in a dry and sanitary condition.

*Article XI—Authorization*

The Department of Health is authorized to require additional or special ventilation or ventilating devices to cover any conditions which are unusual or require special treatment in occupied rooms or spaces in any class of buildings.

*Article XII—Plans*

Before beginning the erection or alteration of any building, the architect or contractor, owner, agent or party in possession or control, shall submit plans and specifications in duplicate showing and

describing in detail the ventilating equipment contemplated. Such plans must be prints taken from tracings drawn to scale on cloth, in ink or by some process that will not fade or obliterate. The plans shall show accurately all necessary dimensions and details and shall be accompanied by a written statement giving the intended number of occupants of each room and the use of the room unless the plans clearly indicate these facts. Such plans and specifications must be submitted and approved by the Department of Health before work is allowed to proceed. During the erection or alteration of any such building, inspections must be made by persons duly authorized by the Department of Health and after completion a certificate shall be issued which states that the ventilating equipment of such building complies in all respects with the approved plans and specifications and with the laws governing the same.

*Article XIII—Officials Empowered to Enter*

The Commissioner of Health or his duly authorized assistants shall have the right to enter any building covered by the provisions of the ventilation law, at any reasonable time, and at any time when occupied by the public, in order to examine such building and judge of the condition of the same and to discharge his duties pertaining thereto, and it shall be unlawful for any person or persons to interfere with him in the performance of this duty.

*Article XIV—Officials Empowered to Close*

Where it is discovered that any violation of the ventilation law is existing in any building the Commissioner of Health shall give due written notice to correct the same. If after a reasonable period this notice is not complied with, the Commissioner of Health shall have the power and it shall be his duty to close and keep closed to the public any such building or part thereof so long as the conditions of violation exist.

*NOTE.—It will be observed that the Committee has used the term "Department of Health" throughout its report, and while the Committee recommends that the enforcement of the laws be entrusted to local health departments in cities and to State Boards of Health in smaller towns, it is evident that, in many cases, the enforcement will be vested in other bodies, in which case the proper name of the body authorized should be substituted for the term "Department of Health" used in the recommendations.*

# SECTION II

## SCHOOLS AND COLLEGES

(Minimum Heating and Ventilating Requirements Applying Specially to all Schools and Colleges. Supplementary to Section I)

*General*: Sufficient and proper heating and ventilation shall be provided and maintained during occupancy in all rooms and all enclosed spaces in all classes of school and college buildings to insure health and comfort conditions, as required by the Department of Health.

### *Article I—Space per Occupant*

a. A minimum of 15 sq. ft. of floor area and 180 cu. ft. of space per occupant shall be provided in each class, study, lecture and recitation room, except that a minimum of 12½ sq. ft. of floor area and 150 cu. ft. of space may be accepted in class and study rooms for pupils under eight years of age.

b. A minimum of 6 sq. ft. of floor area and 90 cu. ft. of space per occupant shall be provided in auditoriums and assembly rooms.

c. Minimum space conditions per occupant in all classes of rooms not tabulated shall be reasonable and practical and shall meet the approval of the Department of Health.

### *Article II—Air Supply per Occupant*

Sufficient outdoor air shall be provided for all occupied rooms at all times during occupancy as may be necessary to meet the requirements of Articles II to VII, inclusive.

A positive supply of outdoor air shall, while school is in session, be provided the following rooms, and the quantity of this positive air supply shall be equal to, or in excess of, the following minimum requirements per occupant per hour:

| | |
|---|---|
| Class, study and recitation rooms | 1800 cu. ft. |
| Auditoriums, lecture or assembly rooms and libraries | 1200 cu. ft. |
| General and chemical laboratories | 1800 cu. ft. |
| Domestic science and manual training rooms | 1800 cu. ft. |

Offices, reception rooms, teachers' rooms, retiring rooms, play rooms, corridors, gymnasiums and lunch rooms, shall have approved ventilation and the ventilation of gymnasiums shall be based upon a minimum of four changes of air in the room per hour, excepting

specific cases, where the Department of Health shall have the power to modify this requirement.

The air supply for ventilation shall be taken from an uncontaminated source, or the air supplied must be air from which the dust or other impurities shall be sufficiently removed by washing, filtering or other approved method.

*Article III—Air Distribution*

The distribution and temperature of the air supply for ventilation shall be so arranged as to maintain the temperature requirement of the following Article IV, without uncomfortable drafts or any direct draft lower than 60° F., and as a test of proper air supply and distribution, it shall be required that the $CO_2$ content shall not be allowed to exceed 10 parts in each 10,000 parts of air, based upon tests of air taken in a zone from 3 to 6 ft. above the floor line in any part of the occupied spaces.

*Article IV—Temperature*

The temperature of the air in the various rooms and spaces within the building during the period of occupancy shall be maintained at all times throughout all occupied spaces within the ranges given in the following schedule, except when the outside temperature is sufficiently high that artificial heating in the building is not required:

| | |
|---|---|
| Class, study and recitation rooms | 65° to 70° F. |
| Auditoriums, lecture and assembly rooms | 64° to 68° F. |
| General laboratories, domestic science and manual training rooms | 60° to 68° F. |
| Gymnasiums | 55° to 65° F. |
| Offices, reception rooms, teachers' rooms, retiring rooms | 65° to 70° F. |
| Corridors | 60° to 70° F. |
| Play rooms, lunch rooms, locker rooms, wash rooms, dressing rooms and coat rooms | 60° to 68° F. |
| Toilet rooms | 55° to 68° F. |

For rooms not named the temperature range shall be 60° to 70° F. according to use.

This article shall not apply to outdoor school rooms, termed "open air" school rooms.

An accurate thermometer shall be provided and remain set and maintained at a height of five feet from the floor against an inside wall of each class, recitation, study and lecture room. One such thermometer shall be placed and maintained in each laboratory,

domestic science and manual training room and at least two such thermometers in each auditorium, assembly room and gymnasium. Provide proper insulation between thermometer and wall.

*Article V—Special Exhaust Ventilation*

There shall be provided for all laboratories, domestic science rooms or other rooms where gases, fumes or other special impurities are released in quantities tending to injure the health of the occupants, suction devices that shall remove such gases, fumes and other impurities from said laboratories, domestic science rooms or other rooms at or near the point of origin. When the Department of Health shall deem it necessary, proper hoods and ducts connected with exhaust fan or fans of sufficient capacity, and operating at sufficient pressure, shall be provided to remove such impurities. Said fan or fans shall be kept running constantly while such impurities are being generated or released, and shall discharge at a point above the roof or otherwise as may be necessary to safeguard the fresh air supply for the building from contamination and prevent any public nuisance.

*Article VI—Special Service Rooms*

General locker rooms, coat rooms, dressing rooms and wash rooms shall have exhaust ventilation equal to not less than six changes of air per hour, except where windows of such rooms open directly to the outside air and are at least equal in area to one-eighth of the floor area of the room. In such cases the exhaust ventilation requirement may be modified under discretion of the Department of Health.

*Article VII—Toilet Room Ventilation*

See Toilet Room Ventilation, Section I, Article IX.

*Article VIII—Heat Sources*

Any heat source which does not contaminate the air and which does not conflict with the requirements of the Health, Fire, Building or Electric Departments may be used both to warm the air supply for ventilation and to provide heat by direct radiation.

*Article IX—Temperature Control*

Temperature control, preferably of an automatic type, shall be required for all heated and ventilated rooms. The temperature regulator, whether by automatic or hand control, shall be so arranged that its operation will not decrease the required volume of air supply for ventilation.

*Article X—Moving Picture Machines*

Where facilities are given for moving picture machines, all ventilation and fire protection shall conform to Section IV, Article VI, and accompanying suggestions.

*Article XI—Gravity Indirect Systems*

Gravity indirect heating and ventilating systems of approved design meeting the general requirements of this Section II may be accepted for small school houses not exceeding eight class rooms, in localities where proper motive power for positive or mechanical ventilation is lacking, provided such gravity system shall, with room temperature maintained at 70° F. and a difference of 40° F. between the temperature of the outside air and that of the air entering the room at the warm air inlet, be capable of supplying at least 30 cu. ft. of air per minute for each pupil accommodated in the room or rooms.

GENERAL SUGGESTIONS FOR SCHOOLS AND COLLEGES

General questions, such as inspection, method of enforcing the requirements, penalties for non-compliance, etc., are left largely for each state, city or town to determine, although some pertinent suggestions covering these matters are made in Section I, Articles XI, XII, XIII and XIV. *Inspection, method of enforcing and penalties are vitally important and should have careful consideration.*

It should be especially noted that the foregoing regulations call for a minimum of all requirements as compulsory, and that it should be the aim of the administrative department having enforcement of the regulations in charge, to encourage the installation of liberal and high-class equipment in our schools for the public inspiration as well as for the health and comfort of the occupants.

In Article I, minimum floor space and volumes for laboratories, manual training and domestic science rooms were omitted because of the wide diversity of existing practice. Values which seem reasonable are:

Floor space, per occupant, 25 sq. ft.; volume, per occupant, 300 cu. ft.

In Article II, "air from an uncontaminated source" comprehends a supply of air, either normally pure as it enters the building or purified by some approved method before being distributed to the rooms in the building.

Elimination of dust from the air supply by means of air filters or air washers is desirable even under the best conditions and is abso-

lutely imperative under some conditions of especially dusty air supply.

The controlling of relative humidity, within the range of thirty-five per cent. to fifty per cent. is desirable, wherever possible.

Rules for opening class room windows, under proper supervision, during recess periods are often valuable.

Strong emphasis is placed on the need of having the administrative feature of legislation, of the kind here advocated, placed in the control of a responsible department, such as a State Department of Health in the case of villages, and a Municipal Department of Health or some other responsible municipal department for cities. It is further urged that such department be supplied with a special inspector or inspectors, experienced in heating, ventilation and sanitation, and that such department be given reasonable latitude by legislation to require approval of plans preceding installation; to require special extra equipment for special cases, such as dust filters or air washers for air supply where the same is especially dust laden; to require fans in the auditorium to keep the air in motion where air distribution is deficient, etc., it being made clear in the legislation that such latitude should in no case include the right to reduce the general legal ventilation requirements.

The Committee recommends that the clauses relating to the power of entry and closure by authorized officers as stated in Section I, Articles XIII and XIV of this report (which have been of great benefit in the City of Chicago), or clauses to the same effect, be included in every ventilation law.

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## SECTION III

## FACTORIES

(Special Minimum Heating and Ventilation Requirements Applying to all Classes of Factories and Work Rooms. Supplementary to Section I)

*Definition*

Any building or room where persons are at work or employed in the manufacture, assembling or repairing of goods or materials which are not for their own family consumption or personal use shall be deemed a "factory" for the purposes of this Section.

*General Requirement*

The owner or lessee or tenant or agent of a building used as a factory, or in which a factory work room or work rooms are located, or the owner, or lessee or tenant or agent of any work room in any building used for factory purposes, shall provide and maintain for every work room thereof and for all allied service rooms in connection therewith (such as office, stock, sorting, shipping, wash, dressing, locker and toilet rooms) good and sufficient ventilation and healthful temperature and humidity conditions at all times during working hours.

*Article I—Space per Occupant*

A minimum space of 250 cu. ft. per occupant shall be provided in all work rooms, and no work room, of which occupancy is taken after the date of issuance of this provision, shall have less than a clear height of 10 ft.

*Article II—Air Supply per Occupant*

A positive supply of outdoor air from an uncontaminated source shall be provided for the work room at all times during working hours, and the quantity of this supply of outdoor air shall be based upon a minimum requirement of 1500 cu. ft. per hour per occupant, introduced in such a manner as to fully meet the requirements of Articles III and IV.

Where the space per occupant is less than 1000 cu. ft. or the window area, opening directly to out of doors, is less than eight sq. ft. per occupant, a positive air supply shall be furnished by mechanical or other means.

*Article III—Air Distribution*

The distribution of the fresh air supplied shall be so arranged as to maintain the temperature requirements without uncomfortable drafts, or any direct draft lower than 60° F. in occupied spaces. (See exceptions under the following Article No. IV.) One test of proper air supply and distribution will be that the $CO_2$ content in any occupied part of a work room shall not at any time exceed 10 parts in each 10,000 parts of air, based upon tests of air taken in a zone from 3 to 6 ft. above the floor line in any part of the occupied spaces. (See exceptions in Section I, Article III.)

*Article IV—Temperature*

The temperature of the air in any work room shall, at all times during working hours, be maintained throughout the actual working spaces, within the range of 60° F., to 72° F., depending upon the class of work and workers—except when the outside temperature is sufficiently high that artificial heating in the building is not required or when the particular class of work requires or makes advisable other temperatures that may be allowed by the Department of Health.

The temperature of the air in offices shall be maintained during occupancy within the range of 65° to 70° F.; in wash, dressing and locker rooms during working hours, 60° to 70° F.; and in toilet rooms 55° to 68° F.

Accurate thermometers shall be provided, set and maintained at a height of 5 ft. from the floor of all work rooms, at least one thermometer for every 2500 sq. ft. of floor area. Provide proper insulation between thermometer and wall.

*Article V—Heat Sources*

Any heat source which does not contaminate the air and which does not conflict with requirements of the Health, Fire, Building or Electrical Departments, may be used both to warm the outdoor air supply and to provide heat by direct radiation.

*Article VI—Special Service Rooms*

Locker, wash, dressing and coat rooms shall be ventilated in a manner approved by the Department of Health. See Section I, Article VIII.

*Article VII—Removal of Injurious Substances by Mechanical Exhaust or Other Practical and Positive Means*

Where dust, fumes, gases, vapors, odors, fibres or other impurities are created or released in the course of a business or process carried on in any work room or other place in quantities tending to injure the health of the occupants, there shall be provided canopies, hoods or other special devices, connected with exhaust fan or fans of sufficient capacity and operated at sufficient pressure to remove such impurities at their point of origin. Such fans shall be kept running constantly while impurities are being generated or released, and shall discharge at a point above the roof or otherwise, if so directed by the Department of Health, and be provided with dust collectors or separators as may be required to safeguard the fresh air supply of the building or adjacent buildings and prevent

nuisance in the neighborhood. If practical and positive means, other than mechanical exhaust, can be devised for keeping these impurities from the air, such means may be used when formally approved by the Department of Health.

Whenever the amount of air exhausted by suction devices to meet the above requirements exceeds the amount of air supply required for ventilation, the air supply for ventilation shall be increased sufficiently to prevent undue air inleakage.

*Article VIII—Excessive Temperature and Humidity*

If, owing to the nature of the work done or the process carried on in a work room or any occupied space in any factory, excessive heat or humidity is caused therein, sufficient to be injurious to health, there shall be provided and maintained special means or appliances to reduce and control such excessive heat according to the requirements of Article IV, and the relative humidity shall not be permitted to exceed sixty-five per cent. except when outside weather conditions prevent or when said rooms are used for special purposes which, according to the Department of Health, require or make advisable other humidities.

*Article IX—Filters and Air Washers*

If, in the opinion of the Department of Health, the air supply to any building is deemed impure or especially dust laden, filters, air washers or other appliances, satisfactory to the Department, must be provided.

*Article X—Air Contamination from Gas Burners*

Where artificial or natural gas is burned in any occupied work room, it shall be the duty of the Department of Health to inspect, and said Department can require special or additional ventilation to overcome any objectionable condition.

*Article XI—Toilet Room Ventilation*

See Toilet Room Ventilation, Section I, Article IX, of the general heating and ventilating requirements.

GENERAL SUGGESTIONS FOR FACTORIES

General questions, such as inspection, method of enforcing the requirements, penalties for non-compliance, etc., are left largely for each state, city or town to determine, although some pertinent sug-

gestions covering these matters are made in Section I, Articles XI, XII, XIII and XIV. *Inspection, method of enforcing and penalties are vitally important and should have careful consideration.*

It should be especially noted that the foregoing regulations call for a minimum of all requirements as compulsory, and that it should be the aim of the administrative department having the enforcement of these regulations in charge, to encourage the owners and operators of said factories to provide as comprehensive, liberal and high-class equipment as possible, with a view to catering to the comfort, health and efficiency of the employees.

Elimination of dust from the air supply by means of air filters or air washers is desirable under the best conditions, and is absolutely imperative under some conditions of especially dusty air supply.

The controlling of relative humidity, within the range of thirty-five per cent. to fifty per cent. is desirable wherever possible.

Rules for airing all work rooms during the noon hour by means of open windows is, under proper supervision, often valuable.

Strong emphasis is placed on the need of having the administrative features of legislation, of the kind here advocated, placed in control of a responsible department, such as a State Department of Health in the case of villages, and a Municipal Department of Health, or some other responsible municipal department, for cities. It is further urged that such department be supplied with a special inspector or inspectors, experienced in heating, ventilation and sanitation, and that such department be given reasonable latitude by legislation to establish rulings within the law to require approval of plans preceding installation; to require special extra equipment for special cases, such as dust filters or air washers for air supply where the same is especially dust laden; to require fans in special places to keep the air in motion where air distribution is deficient, etc., it being made clear in the legislation that such latitude should in no case include the right to reduce the legal ventilation requirements.

Definite penalties, such as fines for minor offenses, up to a closing of the establishment for important or repeated violations, are indispensable to get practical results.

The Committee recommends that the clauses relating to the power of entry and closure by authorized officers as stated in Section I, Articles XIII and XIV of this report (which have been of great benefit in the City of Chicago) or clauses to the same effect be included in every ventilation law.

# SECTION IV

## THEATRES

(Special Minimum Requirements Applying to all Classes of Theatres and Motion Picture Houses. Supplementary to Section I)

### *Article I—Space per Occupant (new places)*

a. A minimum of 4 3/5 sq. ft. (must be at least 33 in. back to back of seats by at least 20 in. width of seat) of floor area as a seating space per occupant, exclusive of aisles and public passageways, shall be provided in the audience hall.

b. A minimum of 90 cu. ft. of air space, per occupant, shall be provided in the audience hall.

c. Aisles shall have in the aggregate a width of not less than 20 in. for each 100 seating capacity, and for fractional parts of 100, a proportionate part of 20 in. shall be added. No aisles shall have a width of less than 30 in.

### *Article I-A—Space per Occupant (existing places)*

a. A minimum of 4 1/3 sq. ft. (preferably 32 in. back to back of seats by 19½ in. width of seat) of floor area as a seating space per occupant, exclusive of aisles and public passageways, shall be provided in the audience hall.

b. A minimum of 80 cu. ft. of air space, per occupant, shall be provided in the audience hall.

c. Aisles shall have in the aggregate a width of not less than 20 in. for each 100 seating capacity, and for fractional parts of 100, a proportionate part of 20 in. shall be added. No aisles shall have a width of less than 30 in.

### *Article II—Air Supply per Occupant (new places)*

A positive supply of outdoor air from an uncontaminated source shall be provided for the audience hall at all times while the show place is open to the public, and the quantity of this positive supply of outdoor air shall be based upon a minimum requirement of 1200 cu. ft. per hour per occupant.

### *Article II-A—Air Supply per Occupant (existing places)*

A positive supply of outdoor air from an uncontaminated source shall be provided for the audience hall at all times while the show place is open to the public, and the quantity of this positive supply of

outdoor air shall be based upon a minimum requirement of 1000 cu. ft. per hour per occupant.

*Article III—Air Distribution (new places)*

The distribution of the supplied outdoor air in the audience hall shall be so arranged as to maintain the temperature requirement without uncomfortable drafts, or any draft lower than 60° F., and as one test of proper supply and distribution, it shall be required that the $CO_2$ content in any part of such audience hall shall not at any time exceed 10 parts in each 10,000 parts of air, based upon tests of air taken in a zone from 3 to 6 ft. above the floor line in the occupied spaces.

*Article III-A—Air Distribution (existing places)*

The distribution of the supplied outdoor air in the audience hall shall be so arranged as to maintain the temperature requirement without uncomfortable drafts, or any draft lower than 60° F., and as one test of proper supply and distribution, it shall be required that the $CO_2$ content in any part of such audience hall shall not at any time exceed 12 parts in each 10,000 parts of air, based upon tests of air taken in a zone from 3 to 6 ft. above the floor line in the occupied spaces.

*Article IV—Temperatures (both new and existing places)*

The temperature of the air in the audience hall during period of occupancy shall be maintained at all times throughout all occupied spaces within the range of 62° F. to 70° F., except when the outside temperature is sufficiently high that artificial heating in the building is not required.

The temperature of the air in dressing rooms, smoking rooms, stage, ante-rooms, ticket offices, toilets and any occupied spaces other than the auditorium, shall be maintained as the special use thereof makes desirable within the range covered by Section I, of the general ventilation requirements.

*Article V—Heat Sources (both new and existing places)*

Any heat source which does not contaminate the air and which does not conflict with the requirements of the Health, Fire, Building or Electrical Departments may be used both to warm the outdoor air supply and to provide heat by direct radiation.

All stoves are prohibited and all gas heaters, except when furnished with ample protection and adequate means for the removal of the products of combustion, are prohibited.

*Article VI—Machine Booth Ventilation (both new and existing places)*

Enclosures or booths for the motion picture machines shall be provided with exhaust ventilation having sufficient capacity to remove at all times not less than 60 cu. ft. of air per minute through a one-machine booth, not less than 90 cu. ft. of air per minute through a two-machine booth, and not less than 120 cu. ft. of air per minute through a three-machine booth. *See "General Suggestions for Theatres" for further details.*

Where picture machines, films, and their equipment are passed as fireproof by the National Board of Fire Underwriters, the Department of Health may, at its discretion, modify the booth requirements.

*Article VII—Air Exhaust System*

Attention is called to the general ventilation requirements for Special Service Rooms, Section I, Article VIII.

*Article VIII—Toilet Room Ventilation (both new and existing).*

See Toilet Room Ventilation, Section I, Article IX.

### GENERAL SUGGESTIONS FOR THEATRES

General questions, such as inspection, method of enforcing the requirements, penalties for non-compliance, etc., are left largely for each state, city or town to determine, although some pertinent suggestions covering these matters are made in Section I, Articles XI, XII, XIII and XIV. *Inspection, method of enforcing and penalties are vitally important and should have careful consideration.*

It should be especially noted that the foregoing regulations call for a minimum of all requirements as compulsory, and that it should be the aim of the administrative department having enforcement of the regulations in charge, to encourage the owners and managers of motion picture shows to provide as comprehensive, liberal and high-class equipment as possible, with a view to catering to the comfort and health of the patrons and thus adding to the popularity of the show place as compared with others which have barely come within the legal requirements.

The eighty cubic feet of air space per occupant, allowed by the recommended regulations for "existing places," has been arrived at as an extreme minimum cubic space which should be allowed per individual when considering difficult cases of old established places.

Ninety cubic feet of air space per occupant is considered minimum for "new places," and should be increased wherever possible.

A mechanical system of exhaust ventilation is desirable for the auditorium of a theatre in addition to the air supply system, but a mechanical system of exhaust ventilation is not made compulsory except where it may be necessary to meet the temperature and air distribution requirements.

The requirement for machine booth ventilation may be fulfilled by having a number of small metal screened openings (equipped with special dampers and automatic appliances with fusible link to automatically close tight in case of fire in the booth) on the sides of the booth near the bottom, aggregating 180 sq. in. for a one-machine booth, 210 sq. in. for a two-machine booth, and 240 sq. in. for a three-machine booth, and a metal or other fireproof flue extending from the top, or the side near the top, of the booth and carried to a proper place of discharge outdoors. The size of this special fireproof vent flue shall be not less than 95 sq. in. clear area for a one-machine booth, not less than 120 sq. in. clear area for a two-machine booth, and not less than 144 sq. in. clear area for a three-machine booth, and in addition it shall be provided with an adjustable damper, operated from the booth and equipped with an appliance containing a fusible link or other device to operate so as to automatically open the damper wide in case of fire in the booth. Provide a metal duct equal in size to the special exhaust duct referred to for the different sizes of booths and connecting from out of doors to the bottom or lower part of booth for the introduction of outdoor air directly to the booth. This duct shall pitch from the booth downward to the outside wall of the building, shall be provided at the inlet with proper louvres or weather protection hood, and shall have an adjustable damper near the booth, said damper to be controlled from within the booth and to be independently equipped with an appliance containing a fusible link or other device to operate so as to automatically close in case of fire in the booth. The machine booth ventilation shall be kept in operation at all times when the booth is in use.

Where picture machines, films, and their equipment are passed as fireproof by the National Board of Fire Underwriters, the Department of Health may, at its discretion, modify the booth requirements.

Elimination of dust from the air supply by means of air filters or air washers is desirable even under the best conditions and is absolutely imperative under some conditions of especially dusty air

supply. This question is dealt with by suggestion in the following general clauses.

The controlling of relative humidity, within the range of thirty-five per cent. to fifty per cent. is desirable, wherever possible, but the Committee decided to omit from the regulations any humidity requirement in theatres.

Strong emphasis is placed on the need of having the administrative feature of legislation, of the kind here advocated, placed in the control of a responsible department, such as a State Department of Health in the case of villages, and a Municipal Department of Health or some other responsible municipal department for cities. It is further urged that such department be supplied with a special inspector or inspectors, experienced in heating, ventilation and sanitation, and that such department be given reasonable latitude by legislation to require approval of plans preceding installation; to require special extra equipment for special cases, such as dust filters or air washers for air supply where the same is especially dust laden; to require fans in the auditorium to keep the air in motion where air distribution is deficient, etc., it being made clear in the legislation that such latitude should in no case include the right to reduce the general legal ventilation requirements.

Definite penalties, such as fines for minor offenses, up to a suspension or revoking of licenses for important or repeated violations, are indispensable to get practical results.

The Committee recommends that the clauses relating to the power of entry and closure by authorized officers as stated in Section I, Articles XIII and XIV of this report (which have been of great benefit in the City of Chicago) or clauses to the same effect be included in every ventilation law.

No. 394

# REPORT OF COMMITTEE ON EDUCATION AND PUBLICITY

Your Committee on Education and Publicity, appointed by President Kimball, have the honor to submit the following report:

In general the engineering professions, and accordingly, the engineers, have developed as a necessary issue of industrial activities. There were telegraph lines before there were electrical engineers; there were mines before there were mining engineers; there were bridges before there were civil engineers, and there were buildings before there were mechanical engineers or even architects. The essential fact is that the engineer appears always after the inception of the art. Engineering as related to building came only when the buildings had become so complex that architects, who fundamentally are artists, became unable, personally, to handle all of the details, as in our highly differentiated modern structures. The same applies in other branches of engineering.

The first engineers were connected with the manufacturing concerns. Electrical manufacturers, e.g., at first made motors, dynamos, lamps, switchboard devices, etc., always in a rule-of-thumb manner. Then certain individuals developed specialties and specialized, thus evolving electrical machinery along scientific lines, economically and with growing precision.

In the meantime there existed a period during which the greater amount of work was done without the assistance of especial electrical engineers, but engineers grew in number with time and the amount of empirical work has diminished, until at present the profession is highly specialized, and little, if any, manufacturing is done without the direct assistance of engineers. The Heating and Ventilating art has been and is experiencing precisely the same process of evolution above exemplified. At

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Presented at the Annual Meeting of The American Society of Heating and Ventilating Engineers, New York, January, 1916.

a time when there were no Heating and Ventilating engineers, naturally these could not have been hurt by neglect; but just now much work is being done without Heating and Ventilating engineers, and the smaller amount of work is done with their aid. Manufacturers of Heating and Ventilating devices are taking a leaf from the experience book of the electrical manufacturers and employing engineers in their offices and works. In the Electrical and Mechanical fields, the manufacturers' engineers often have acted as consultants to prospective customers, and a condition existed wherein the manufacturer stood in an advisory relation to his clients, telling them which machines to employ and how to use them.

What has been said in reference to electrical manufacturers applies equally to blowers, boilers, radiators, air-washers, valves and other Heating and Ventilating devices. It has been necessary for manufacturers to act as consultants, but the tendency of the manufacturer is always to confine himself to his legitimate function and only to manufacture and sell machines. Consequently it becomes inevitable that a class of experts or specialists be evolved who shall act as links between the manufacturers and the consumers. These are the consulting engineers, whose province is analogous to that of the architect. They advise the customers as to the best disposition, arrangement and operation of their machines and they select these only with reference to the best interests of the customer. These expert engineers, in the established branches, experience no difficulty on the score of being able to collect consultants' fees.

The difficulty with the Heating and Ventilating Engineer seems to be that his organization has not yet so far developed that he is generally known to, and appreciated by the lay public as the necessary element in the industrial community which, indeed, he is. We think that the fundamental problem is how to have the Heating and Ventilating engineers become widely known. People cannot be expected to pay for anything the existence of which they are not aware of. When buildings were simply architectural creations without engineering structure, engineers did not receive specific fees for what small assistance they rendered the architects, but with the advent of the modern steel sky-scraper and other highly developed industrial structures which are now so common, it is accepted as a matter of course that an engineer be retained as well as an architect. Up to now the Heating and Ventilating engineer has been regarded as being concerned with something that comes in the

natural course of events and he is accepted too often without being recognized. Many people build buildings without ever knowing that there is any Heating and Ventilating or Sanitary problem involved. The problem falls to an architect who solves it as best he can, if it be simple. If the case be complex, the architect seeks help outside, and naturally, being human, he seeks it where it can be obtained cheapest. In the majority of cases this is from either a contractor or manufacturer, who, to get the business, does the engineering for nothing, and in general, it is worth what it costs. Too few people are alive to the value of, or indeed know of the Heating and Ventilating engineer. Therein lies the fundamental difficulty which the profession is now experiencing and the solution will be found in the engineers' becoming widely known.

Another essential difficulty which confronts the Heating and Ventilating Engineering profession is the inadequate preparedness of entrants into its ranks. The profession has evoluted from the empirical, practical and generically non-technical manufacturers, each of whom has worked his own problems as trade individualisms. The broad fundamental essentials of the art have not been widely diffused by its founders, but instead, have been treasured and guarded as trade secrets. Consequently, manufacturers and consulting engineers must seek for new men either from among shop apprentices who have little or no technical education, or from among college graduates who possess no practical experience and little technical knowledge of the branch of engineering they are about to enter. The universities and technical schools have not generally recognized Heating and Ventilating as a separate and specialized branch of engineering, and the trades, in general, have not advocated the general dissemination of knowledge of how to ply their callings.

The deliberations of your committee have been concerned, firstly, with ways and means of promulgating widely the specialized technical information of the Heating and Ventilating Engineer for the general welfare and development of the profession, and, secondly, with the proper presentation of the profession of Heating and Ventilating Engineer to the public it serves.

The work has been undertaken under the superintendence of four sub-committees, viz.:

Scope of Engineering Education and Faculty,
Popular Lectures and Publicity,
Professional Ethics,
Finance.

An educational propaganda, professional and public, popular lectures, an ethical campaign of newspaper publicity, are among the suggested points of attack. The public should be taught to recognize that this is an important branch of engineering which should be as widely known and recognized as are the other engineering professions which have been in the public eye for longer periods.

Your Committee recommends the preparation of a series of text-books forming an encyclopedia on the subject of heating, ventilation and sanitation, to be issued by the Society and prepared by its members as far as possible, with contributing sections from external sources where found expedient. This set of text-books would form the basis of instruction to be given under the direction of the Chapters of the Society in all places throughout the country where suitable men could be found to conduct classes; and, as a part of this general educational work, a standardized syllabus could be prepared covering a course of lectures, and graded diplomas could be given by the Society certifying as to the amount of work done by the students; these diplomas having two or more grades as might be developed by the Committee appointed to take charge of such work. The encyclopedia should contain a carefully edited review of the past work of the Society and should be complete with data from the best available and most reliable sources.

The problem of press notices for the Society and the profession has been considered at some length as well as that of lectures of an educational and non-technical character for the public. We feel that the profession can render the general public an invaluable service in educating them to the appreciation of the importance of suitable sanitary engineering measures in conserving public health. Proper appreciation of the profession by the public will react beneficially on the public itself in that it will benefit by the inevitable growth and increased beneficent productiveness of the profession.

The Sub-Committee on Ethics and Welfare has made a study of the codes of the various professions and is impressed with the negative, repressive character of most of these. They savor of "Thou shalt not!" Your sub-committee has outlined a broad ethical standard of humanity and fraternal co-operation which it is respectfully hoped the profession of Heating and Ventilating Engineers shall adopt in their dealings with their colleagues and their clients.

The matter of finance naturally has had to be considered more or less tentatively. The Chapters giving lecture courses will be under little expense other than rental and traveling expenses of lecturers. It is shown how the fundamental project, viz., the text-book, should amply pay for itself and how the traveling expenses of the lecturers to the public should be borne by the local organization under whose auspices the lecture might be given.

The reports of the various sub-committees follow:

## REPORT OF SUB-COMMITTEE ON SCOPE OF EDUCATION

The Sub-Committee on Scope of Education has the honor to present the following report and recommendations:

We believe that due consideration has been given to the various phases of this subject, among them being the question of lectures in Universities, the giving of special courses of study by Chapters located in New York City and other points, the formation of special courses in Universities, and the value of popular lectures for the general public on the subjects of Heating and Ventilating.

This Committee considers that it is very desirable that this Society should undertake the publishing of a text-book covering the subjects of Heating and Ventilating, thoroughly. This text-book would consist of a collection of monographs contributed by the best authorities available. The form of this text-book might be a single volume or might appear as a series of monographs under separate covers, duly numbered and interrelated.

It is believed by the Committee that it would be possible to secure men who are experts and authorities on each of the subjects, to write chapters for this book, and we also believe that it is possible to combine the work of two or more authorities on the same subject in such a manner that these authorities will be in thorough agreement on the matter printed. In this manner, the Society will not have to lend itself to further the commercial interests of any device, appliance or system. In other words, it is the belief of this Committee that it is feasible for the Society to undertake to publish a text-book, every chapter of which shall be prepared by men who are recognized authorities in their particular line and that this book will be of such great value that it will be adopted universally by Universi-

ties and others having courses in Heating and Ventilating, and will be one on which this Society may well be proud to stamp its approval.

This Committee further considers that the Society should encourage the establishing of courses of study in connection with Technical Schools whereby Post Graduate Courses on Heating and Ventilating may be given and that similar courses of study presented in the form of lectures might be given by the various Chapters wherever expedient The course of study should be prepared on the assumption that the matriculants shall have thoroughly mastered a High School education, including Algebra through quadratics, Plane and Solid Geometry, Plain Trigonometry, Elementary Chemistry, Elementary Physics and Mechanical Drawing

It is our belief that graduates from the various Universities and Technical Schools should be able to master the course outlined probably within six months and certainly within nine months, or the usual collegiate year. It is recommended wherever such courses are established, that they require not only completion of the course of study outlined, but also that some time be given to experimental and research work under the direction of the instructors in charge. It is believed that the work in the Technical Schools should be carried on like other instruction given in these institutions, but the course recommended for the various Chapters could take the form of lectures as in one case the recipients of the course would be undergraduates without practical experience who would require regular classroom work in order to impress the facts on their minds, while those attending the lectures would be no doubt drawn largely from men who may or may not have received a Technical Education but who are actively engaged in the profession and who would receive a much greater instruction from lectures than would be possible for undergraduates.

We attach herewith a suggestion of a synopsis of the subjects to be treated, for the consideration of the Permanent Committee in case the Society sees fits to adopt this report.

In reference to the selection of a faculty, it has seemed to this Committee that this may be left until after action has been taken by the Society upon the report of the General Committee of which his report will form a part.

SYNOPSIS OF PROPOSED EDUCATIONAL COURSE IN HEATING AND VENTILATING ENGINEERING.

I. GENERAL

1. General Introductory
2. Physics
3. Physiology

II. HEATING

*A. General*

1. Standards for heating buildings
2. Heat transmission
3. Heat losses
4. Combustion and its relation to heating apparatus
5. Chimneys and their relation to combustion and heating apparatus

*B. Methods of Heating*

1. Warm Air Furnace Heating
   (a) Gravity systems
   (b) Fan systems
   (c) Combination systems
   (d) Heat transference by air
2. Radiation
   (a) Direct
   (b) Indirect
   (c) Blast
   (d) Surface and temperature
3. Hot Water Heating
   (a) Gravity
   (b) Gravity under pressure
   (c) Forced circulation
   (d) Apparatus
      boilers
      pumps
      special appliances
4. Steam Heating
   (a) Gravity systems
   (b) Return line systems
5. Gas Heating
   (a) Stoves
   (b) Furnaces
   (c) Radiators
   (d) Steam and Water Boilers

6. Electric Heating
   (a) Direct
   (b) Hot water

C. *Apparatus and Appliances*

1. Pipe systems
2. Return traps and pumps
3. Pipe coverings and insulation materials
4. Various special appliances

III. VENTILATION.

1. Special Physical Laws
   (a) Data of Atmosphere
   (b) Contamination
2. Standards
   (a) Amount of air required
   (b) Humidity, temperature, air movement
   (c) Quality
3. Humidity and air movement
4. Cleaning and dust removal
   (a) Bacteria
5. Flow of air in ducts
   (a) Laws
   (b) Computation
   (c) Friction losses
   (d) Sound transference
6. Blast coils and radiators
7. Temperature regulation
   (a) Manual
   (b) Automatic
   (c) Economy
   (d) General considerations
8. Fan engineering
9. Special appliances and apparatus

Respectfully submitted,

J. I. LYLE, *Chairman,*
JAMES A. DONNELLY,
PERRY WEST,
F. L. PRYOR,
C. L. RILEY,
SUB-COMMITTEE ON SCOPE OF EDUCATION.

## REPORT OF SUB-COMMITTEE ON PUBLICITY AND PUBLIC LECTURE COURSES.

The Sub-Committee on Publicity and Public Lecture Courses have the honor to present the following suggestions and recommendations:

The Committee beg to report that they have carefully considered the question of publicity as related to the general subject of heating and ventilation and respectfully make the following specific suggestions:

1. That a complete outline of the scope of the work now being undertaken by THE AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS Committee on Education and Publicity be prepared; this report or outline to be written in a popular style and given to the leading newspapers and periodicals and particularly those periodicals which are read by the general public, bringing out most clearly the effect of proper installation from the health standpoint. It is thought that an outline of this character, properly written, would be acceptable for publication in all of the leading newspapers throughout the country and could probably be syndicated in a manner similar to the McCann articles on "Food Adulteration" and other articles which have a country-wide circulation.

2. From time to time a digest of the movement could be given to the public through these same channels and articles of a semi-technical character giving a general outline and description, advantages, disadvantages, limitations and relative costs of the various systems of heating and ventilation for residences. It is thought that such a presentation would be highly educational and would stimulate a desire for the best, within the means of each individual and would tend to advance the standard of residence heating and ventilation.

3. We recommend that the Society secure and keep on file, copies of all books on heating, ventilation and sanitation for the use of its members and it is thought that a considerable portion of such books might be donated cheerfully by publishers or officers.

4. It is thought that the Encyclopedia above mentioned should be outlined and a general idea of the size and cost of same determined and that subscriptions be secured in sufficient number to justify the undertaking, and incidentally to give it some valuable publicity prior to its appearance.

5. Suitable articles should be prepared from time to time covering the evil effects of over-heating, lack of ventilation, lack of heat regulation, effect of abnormal humidity, and on the subjects of ozone treatment of air, air movement, carbon dioxide content, and other characteristics of heating, ventilation and sanitation which have a distinctly human interest, and these articles should be most carefully prepared and written in an interesting style. It is thought that such articles could readily find a place in the daily press, Sunday press and the family magazines.

6. An attempt should be made to raise the standard of the work done by Consulting Engineers in this general field and to bring the attention of prospective owners of the desirability of employing experts to design and superintend the installation of heating, ventilation and sanitation; this education should be given to owners in such a way that they would require the architect to employ an expert on this particular branch of the work.

7. Popular Lectures: It is submitted that popular lectures be prepared and lantern slides illustrating the same be made available so that sets of lectures and slides could be sent either with or without a lecturer to various parts of the country to give publicity from the popular or scientific standpoint, as may be required. It is thought that at least four lectures and probably six could be given at each of the Chapters and before some representative organization in each of the larger cities where no Chapter has been formed, each year and that such lectures could also be given before the various architectural and other technical societies and universities which would tend to popularize the general subject and to impress upon architects the desirability of employing proper talent for this important work.

8. Lectures could probably be arranged for in the various leading universities under the auspices of the Society which would tend to popularize the subject and to call attention to the dignity and importance of the Society's activities.

9. In the preparation of data, both for the encyclopedia and for the lectures, the various universities having testing laboratories should be approached with a view to co-operation in making specific tests of the performance of apparatus installed under varying conditions, so as to produce reliable data on the quality and proper operation of various systems in use.

10. As a part of the work of preparation for the lecture courses, a thorough study should be made of electrical heating

and the use of oil as a fuel instead of coal; also the various grades of coal and their characteristics such as heat content, sizes, kinds and adaptability for combustion for various kinds of apparatus.

11. Lectures could be arranged to be given throughout the country before the men's and women's clubs of churches and other organizations.

12. It is recommended that the Society avail itself of every opportunity when invited to attend or be represented at a convention, and that they offer to prepare and have presented by a qualified member, papers at such conventions wherever this appears expedient.

13. We recommend that the Journal of the Society be used wherever possible as a publicity medium.

14. We would suggest the appointment of a committee to prepare a suitable list of subjects for lectures, this committee also to prepare a synopsis of the lectures.

Respectfully submitted,

W. S. TIMMIS, *Chairman.*

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## REPORT OF SUB-COMMITTEE ON ETHICS AND WELFARE

Your Sub-Committee on Ethics and Welfare have the honor to submit the following report:

The first steps taken in the work laid out for this Committee on Ethics and Welfare was to study the matter somewhat in the light of the work done by a similar committee of the New York Chapter.

The codes were collected from other organizations and though the collection is not complete, enough were gathered to learn what other bodies had laid down for the guidance of their members. For the most part these seem naturally selfish and negative in character. The impression had grown that a code of ethics for this body should be along different lines. It should advocate positive things. It should promote attempt to achieve something practically ideal rather than prohibitory in narrower interests. It should promote public interest and thereby best serve the interests of the engineer. It should consider the humble dwelling as well as the public building of great cost. It should

indicate the course the engineer should pursue to have people realize the benefit of having his advice. It should give a schedule of proper fees, as it was discovered in the absence of one that charges entirely too low were prevalent. These are but a few of the ideas that come up and which have not been threshed out and formulated. The work has seemingly accomplished little more than to have given some agitation to the subject and to have shown that it is important and entitled to the concentrated attention of the general membership. It would seem that the work should proceed through the preparation of letters, asking for needed information, sent to engineers, whether or not members, with the view of finding out the true situation, the things for which the profession feels there is a need, and then a work that grows in importance as it is studied may be conducted to a result that will be commendable and eventually acceptable as the profession rises in appreciation of it and adopts it in practice. It is not an excuse but a statement of fact, that those to whom this work has been entrusted were so occupied with the demands of their vocations that it was impossible to meet, and that in some measure is the reason that nothing more tangible is now offered. The matter bearing on the subject comes from the following sources:

The American Institute of Architects.

The American Society of Mechanical Engineers.

St. Louis Sheet Metal Contractors.

The report of the Committee of New York Chapter in Vol. XXI of the Transactions.

The American Association of Engineers.

The American Institute of Consulting Engineers.

There are other codes in existence that should be added to the collection for consideration. They seem too long in most instances. They should be terse and pertinent. A code should be clear, concise, inspiring, practicable and useful.

The work so far has been collective and suggestive and it is hoped that it shows the importance of having a committee better situated to take it up here and carry it forward.

Respectfully submitted,

FRANK K. CHEW, *Chairman,*
R. P. BOLTON,
C. B. J. SNYDER,
C. A. FULLER,
G. W. MARTIN.

## REPORT OF SUB-COMMITTEE ON FINANCE.

Your Sub-Committee on Finance begs to submit the following report:

The proposed campaign of education and publicity is fortunately so constituted that very little difficulty should be experienced in meeting the expenses which will result. The text-book should yield a comfortable profit which could be devoted to the furtherance of the general work of the committee.

The public lectures will involve some small expenditure for lantern slides, printing, stationery, correspondence, traveling expenses, etc.

A fund, whose magnitude can be computed only when definite steps shall have been decided upon, must be raised to meet the immediate expenses of each project.

The publication and financing of the text-book probably will be undertaken by some one of the established technical publishing companies, but there will be some outlay incident to the activities of the committee in securing the material from the different contributors. The most desirable potential authors will have to be approached personally and persuaded to cooperate. This is especially true because they are busy men and will be requested to make their contributions gratuitously.

In the case of the lectures, the Society should be expected to defray the expenses of such lecturers who prepare material on invitation. Where lecturers are sent to colleges, clubs and the like, on request, these will be requested to defray the traveling expenses incurred, but where the Society sends a representative to a scientific convention, his expenses should be assumed by the fund.

Lecture courses where given by any Chapter, should represent private work of that Chapter and financing should concern that Chapter only. This applies equally to public lectures given under the auspices of any Chapter.

Respectfully submitted,

HOMER ADDAMS, *Chairman.*

We should like to impress upon you that, whilst it may appear in this report that all the efforts of the Society are to be directed towards the betterment of the consulting engineer, this is by no means its object. Engineers include those men who are in technical charge of manufacturing quite as fully as it does those

whose vocation is to design and construct industrial edifices wherein these apparatus are utilized. If the organized Heating and Ventilating profession but bend its efforts toward subdividing the different phases of the work so as to encourage and facilitate specialization, it can not but result advantageously to everyone either directly or indirectly concerned with the broad subject encompassed by the art.

Engineers, whether consulting or manufacturing, are business men in no less sense than are manufacturers and salesmen, but they are specialists, and, indeed, so are the latter.

The engineer's object is to make business, and though this sound crass and utilitarian, it may nevertheless be quite ideal, for no business that has not for its ultimate end the argumentation and furtherance of human happiness can hope to survive.

By opening the doors of our storehouses of knowledge, by giving freely so that all might benefit by our professional and technical labors, we raise the standard of the whole calling and thus raising the standard we gain wider recognition and respect and our services are more widely sought. There is greater demand for the commodity which we merchant, and all of us must benefit by a policy, which, viewed narrowly, might seem disadvantageous to the better endowed. By diffusing our knowledge and mutually interchanging the fruits of our experiences, we all grow, if only in that reduplication and paralleling of similar effort be saved.

Most professions have learned this, and no profession has risen to the true dignity of a learned profession without first having appreciated fully this great truth.

It is sincerely trusted that THE AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS will accept this report and take immediate action toward launching the project submitted.

Respectfully submitted,

MILTON W. FRANKLIN, *Chairman*,<br>
J. I. LYLE,<br>
FRANK K. CHEW, } COMMITTEE.<br>
WALTER S. TIMMIS,<br>
HOMER ADDAMS.

New York, Jan. 18, 1916.

## DISCUSSION

Perry West: It seems to me that the three subjects treated here are each of sufficient importance to be handled by a committee, and I move that a committee be appointed on each of these three divisions. It seems to me that all the matters treated are of equal importance as far as carrying forward at this time is concerned, and each should therefore be handled by an individual committee.

I think we all realized at the outset, that to get the required results, quite a large amount of both talent and money would have to be expended. From the report of the Finance Committee, I do not find that it is definitely set forth as to what the cost will be, either in the expenditure of time, energy or money and I would suggest that the Committee be left to study that subject out more thoroughly and make a definite report. It simply says that the Committee considers it certain that a text-book would be universally adopted by the colleges at the outset, and that the returns would amount to more than the costs. As the cost is heavy, I think we should know definitely whether such would be the case before we go ahead. Another question involved is as to getting men to prepare various sections of the book. We believe that men could be obtained, but I think the Society should know definitely whether they can or not.

The Finance Committee suggests that the cost be underwritten, which I take to mean more or less by contribution, but I do not think the membership would want it to be handled in such a manner. Money should be raised by the members in general and not by the few who might naturally feel a greater interest in this subject. The matter must be undertaken by the entire membership, if it is to have the proper spirit.

F. K. Davis: I move that the Committee on Education and Publicity be made a standing committee.

R. P. Bolton: In view of the fact that this Committee has gone so deeply into this subject, and taken so much time and trouble with the report, it seems that it would be desirable to request them to continue the work in the interests of the Society. If this motion should prevail, that this simply be a standing committee, we would have to go through the process of re-appointment under each president. It seems that the sim-

plest process would be to ask that the entering president reappoint the same Committee on the work.

J. I. LYLE: Making this a standing committee will never accomplish anything. If anything is to be done with this report, it is necessary to empower the committee to carry out something definite.

M. W. FRANKLIN: I assure you that the men of this Committee who have done this work with very little assistance from me, in spite of reports, have done something that judged in our American terms of dollars and cents, it would be impossible to value. They have given time and trouble beyond the ordinary comprehension of most business men. Men who have been so busy that they have had to neglect their families, have sat and worked on this Committee. This report should not simply be passed up by the ordinary procedure of accepting the report.

Of course, if the report is accepted, it is an honor to that Committee that compiled it; if a standing committee is appointed, that is another honor, but unless the Society takes some definite action to further this work, it had better be dropped at once. The amount of work has been great, but it amounts to nothing if this undertaking is not to be perpetuated.

One of the suggestions was to get all available heating and ventilating knowledge together, for there are no text-books on the subject, in this form. The work is scattered broadcast through all general technical works, and it has never been properly compiled in one text-book. We want such a text-book. We feel that we have sufficient talent in our Society to contribute to this book, which will be something that is a standard, a classic, and we request the authority to do this.

We want a committee appointed with authority to get various men to contribute an essay or paper that can be used next to the contribution of another expert, the whole to form a complete heating and ventilating library. If the Society published this and offered it, it would be adopted without question. The committee should have the authority to get this financed in any available way that would be considered ethical; but the chief thing is for the Society to give this committee such authority.

Mr. Timmis' Committee has spent time and thought on the subject of publicity. We wish to develop the heating and ven-

tilating engineers. Relatively, heating and ventilating is a new branch of engineering. The public does not know and never has known of the work of these engineers. We want particularly to bring before them the broad work of the heating and ventilating engineer.

The publicity committee should have popular lectures arranged on the general topic of Sanitary Engineering. When we consider the interest manifested to-day in this subject, in the proper sanitation—covering the broad field of heat, light, air, etc.,—in factories and other places where large numbers of workmen are employed, we should realize that the heating and ventilating engineer is foremost in this work, and should be considered by the public and known better than he is.

(At this point it was decided to defer further consideration of the report to a special session held Thursday morning, January 20, 1916.)

M. W. Franklin: Referring briefly to what this Committee stands for, and what the idea behind the work is: The heating and ventilating profession has risen now to the dignity of the learned professions. An engineer is now in the same class as a lawyer, a doctor or a minister of the gospel—that includes the mechanical engineer, the civil engineer, the electrical engineer, in fact all the broad class of engineers. The complications of modern civilization have made essential the branching out of engineers. There was a time when the mechanical engineer took all the work that now falls into the realm of the sanitary engineer and the electrical engineer. The civil engineer antedated the mechanical engineer and he carried along the work that is now recognized as the specific work of the mechanical engineer, and mechanical engineering is to-day a branch that has grown from the civil engineer who originally did *everything* in the engineering line.

Heating and ventilating engineers have made a beginning, and it is now realized that their necessity is special. It is very apparent to any one that has been concerned with heating and ventilating engineering, that in view of the large amount of attention that is being given to the broad subject of sanitary engineering—in the realms of industrial life, particularly, and in connection with the school house and barracks work—the work of the heating and ventilating engineer covers almost every phase. Under the head of sanitary engineering comes heating, ventilating, lighting (for lighting has a great effect

upon the general health of the worker) sewage disposal, and many special forms of apparatus such as toilets and, in cases of hospitals, numerous other points—broadly, everything that is needed for the special purpose of dealing with the welfare of workers of all kinds.

The engineering societies have grown in the natural course of events, like everything else, by a process of evolution—in some cases offshoots from other branches. We are experiencing a process of this kind; we are the offshoot of several branches. We have grown up from the men who made their own appliances, were their own engineers, and who later designed the apparatus that was to be used; in fact, we find the characteristics of all the branches among us. Natural processes of growth in general are slow, and not only slow but wasteful. The object of this work has been to present to you the question whether we choose to have the heating and ventilating engineers develop in the same way that the other engineers have developed, by the natural process, or whether we want to make use of the vast knowledge of experience and development to which we are heir, and develop our Society in a way that would best aid its growth and promote its existence.

We say that heating and ventilating engineering shall include all the sanitary engineering features that come within the scope of the work that we represent, and we want our work to benefit the Society and the profession generally. Are we willing to make an extra effort and start toward building it up properly, outlining first what we want to do and then building into the outline, or are we going to be content to take the natural course and just slowly evolutionize? Which process of growth are we going to have, the natural slow development, or one where we shall outline our purpose and then fulfill it?

The thing that first appeared to the Committee was the scarcity of, or rather the incomplete available literature on the subject. For a man to get an adequate education in this work, now, it is required that he shall consult a diversified number of publications. He has to seek among greatly varied literature to get the fundamentals of the work and there is nothing under one head that is of any aid to him in getting information that will make him a heating and ventilating engineer.

Reading is the function of the work that we should be able to facilitate; help the man to keep abreast of the times, and the work of others. Reading will enlarge the scope of the indi-

vidual, and if we try and classify and index and unify this vast literature, and have a connected narrative of the whole art, even if we add nothing original, we shall have done a great deal.

A way in which the Society could do this would be through the method of presenting a paper. The present method is for any man who feels that he can make a contribution to make it, and it is usually along the line of that particular man's interest. As a result, our Journal is a heterogeneous mass of articles on all subjects, all thrown together, and leaving a number of gaps that it will take years to fill in. Maybe in fifty years, by this method, we would have a complete work, whereas it could be accomplished in a year or two by proper effort

The work of the Committee has been concerned particularly with three things: *first,* the scope of engineering education; *second,* publicity, or how the profession shall be brought before the public—how shall we introduce to the public whom we are striving to serve, the knowledge of the existence of the heating and ventilating engineer as a specialist, a man who is trying to accomplish something definite in the world's work. The Sub-Committee on Education and Publicity has done excellent work, for which this Society's thanks is due Mr. Timmis. The *third* is welfare and ethics. It seems unavoidable that in the work of a technical nature, there must be a code of ethics in dealing with the public.

We are beginning to find an acute necessity for becoming technical and scientific, of being able to have in our work men with the combination of scientific training and practical knowledge, to understand technical problems and solve them. A pure scientist as an engineer is not the best one; the finest engineer is the combination of the scientific and the practical, a practical technician with sufficient skill to apply the science which is necessary to the art of producing things. The engineering profession is not entirely an altruistic one, but I believe the calling of an engineer is the most dignified one of our time, in all the varying branches.

Several ways have been thought of, in which this effort may be carried forward. At first we thought of giving a course that would be conducted by the Society, and we would endeavor to have the members take into their employ young men who had had the advantage of this course, in the way that many men now take only men who have had a college course. But

this project seemed inadvisable after considerable deliberation and discussion.

Then we looked around for a substitute and prepared a recommendation that the Society make an effort to get articles on the different branches of heating and ventilating engineering, that put together would form a connected narrative, a text book that would be the final word in engineering. Such a book could be well gotten up. We have all the experts connected with us either directly or indirectly, and they would all be willing and glad to contribute something to such a book.

Having this text book, we could approach the colleges, trade schools, Y. M. C. A's, every place that is likely to provide a course, and endeavor to have them adopt this. We could also encourage the Chapters to give night courses. Then there would be an opportunity for the young fellows to get something that would be of value to them if they wanted to follow this line of work.

In every branch of engineering the public is being approached in some way so that they are brought into knowledge of the engineer and his work. Articles in popular form appear for the education of the public, some of them semi-technical, and they even appear in the Sunday papers and magazines. They appeal to the large class of people. What could be better than to have some of these articles in our line: How to Heat a House; How to Conserve Heat; How to Obtain the Best Results with Efficiency; and similar subjects could be well treated. We could also include articles on some of the sanitary matters that seem so interlaced with heating and ventilating.

The Sub-Committee has outlined a very beneficial course for the public that it would be well for the Society to consider. If the public is awakened and interested, not only the public would benefit, but the Society and the profession as well. I make no apology for bringing up the utilitarian intent in what I am saying. Men who are men, are out for business, and we want to advance the art and at the same time, benefit every one who is connected with it.

The Publicity Committee had in mind in regard to these articles, that the members should be asked to write the articles that would appear in popular form in the magazines and Sunday papers. We should all put our shoulder to the wheel and give the benefit of our experience in every way possible. In presenting the series of lectures, we would have to develop

men who are capable of giving talks at women's clubs, city clubs, Y. M. C. A's, scientific conventions, and every place where we think there is a place for legitimate publicity. The Society should have a set of slides and outline the subjects for presentation, and then offer them to such organizations. It would soon become known that THE AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS was in the work of diffusing technical knowledge which would be of benefit to the public.

Little can be done to formulate a scheme of finance until something is done that requires financing. With regard to the text-book, I am certain that we shall not have the slightest difficulty in publishing the book, without cost, but rather with a profit to the Society. The modus operandi is this, that the committee be authorized to collect all the available material for such a compilation, and that it either be published in the Journal, in which case the cost of type-setting would be absorbed, and thus not add a burden of expense to the Society, and afterward be printed in pamphlet form, edited and indexed so that as the material accumulated the text-book would grow. We would encourage the adoption of this book in the different courses where heating and ventilation would be included. Or else, we could go to any of the technical publishers with the full expectation that they would be glad to publish such a unique text-book; they would assume the responsibility of getting it out and give the Society a royalty.

There may be some financing in connection with the lectures, but it will be small. If a good paper is presented at a lecture and the subject appears to be of interest, any Chapter that wants it for their meeting will, ipso facto, be glad to pay for the trouble and expense of the lecturer, if they believe the benefits to be derived will be commensurate with the outlay.

PRESIDENT KIMBALL: I can assure you that lectures will be acceptable. I have had requests from Rochester and Nashua, Tenn., to lecture on this subject, and if more lectures were available, I am sure we would find many opportunities to present them.

WM. KENT: I am pleased with the work done so far, and I move that the report be accepted and the work that has been done by this Committee continued. The scheme proposed is very ambitious. I do not know that any society in this country has ever taken such a step as to provide a text-book. One of

the German societies did work of this kind, and produced the "Hütte" reference book.

I do not think that the Committee understands the difficulty in getting out a text-book. We have text-books now which are probably as good as the general text-books in any other engineering line. If the Society intends to get out a text-book the first thing to be done would be to employ a man at not less than $5,000 a year, to do nothing but digest the existing literature and classify it under the headings to be used in the book. That digest would have to be printed and sent out for criticism and expressions of opinion. Men in the different lines would have to contribute to each subject, hot water heating, furnace heating, vapor heating, etc.—two or three men on each subject, and then the digest would have to be recompiled. I was told many years ago by an officer of the International Correspondence Schools that when they wanted to publish a pamphlet on electrical engineering, they gathered, at about a cost of $3,000, different contributions, and worked a number of years on it, and in the end all the matter was rejected, and the work had to be done over again.

I have had somewhat the same experience myself. The matter contributed is often good, but it is not in text-book form. I have been paid $9.00 a page for such work myself, and have paid a similar figure to others. I assume that it would cost about $20,000 to put this book out; about $10,000 for the preliminary work and $10,000 for the printing. I believe it would cost much more than the Committee realizes.

R. C. CARPENTER: I am pleased to add my approval to the statements made by Mr. Franklin. I think he has outlined a very desirable field of work, which we all know would be profitable to the Society and to the profession. How much of the work would prove practical would depend upon conditions. Only one Society that I know of has ever done similar work, and that was the Society of Automobile Engineers. They undertook to bring out a text-book on these same lines seven or eight years ago. It did not work out exactly as they had expected it to do, but it was useful. It worked into the appointment of a committee on standards, whose work has been very valuable, and the text-book that this committee has published is very valuable to any one who understands the principles that underlies the art. I have hopes that our Committee will include

in their work such work as has been done by that committee, in which event their work will prove very useful.

S. R. Lewis: The subject is very near my heart because I was once on a Publicity Committee myself. I think it will be easy to raise money, and we all have confidence in our Committee. I think the Committee should be continued and provided with the freest possible rein in governing their activities. I would suggest that this session recommend to the Council the sending out, at such time as may be possible, a notice to the members that each is to be assessed $5.00 to further the work of this committee. We ought to raise $2,500 easily.

John R. Allen: It is hard for me to say anything beyond what has already been said. The program is indeed an ambitious one and may result in profit. Of course, when you are writing a book on heating, you should specify whether the book is to be a treatise, or a text-book. The treatise never makes a good text-book and the text-book is not a good reference book. The Committee should be decided as to which type of book they wish to produce. And I don't think I should figure on much profit from a book of this kind; I have had experience writing books and I never found any profits.

In regard to lectures, we have a university extension course, and I have never found that lectures on the subject of heating and ventilation were popular with the public. They would rather have a lecture on some other more popular subject. With engineering societies and educational institutions it would be different; there would be a demand for lectures of this kind.

Another suggestion is that we should co-operate with the universities, and encourage them to co-operate in their experimental work. I think if the Society could do this, it will be doing much to prevent necessary duplication in the various lines of experimental work carried on by the various universities.

President Kimball: In connection with a reference library, the New York State Commission on Ventilation has been to considerable trouble and expense in collecting a library on this subject. It is indexed, and cross-indexed, and will be the most complete collection of books on this subject that can be had. This Commission will cease to exist within the next two years, and that library must be disposed of. I have had the idea that we might make application for it. I think that we could keep it in our offices, if we had the space. We might assure the

Commission that we would co-operate with them. At the present time, we have in our offices a library of about 40 volumes which was left to us.

DR. E. V. HILL: Regarding the library of the New York Commission, you may find that you have a competitor in trying to secure it. The Chicago Commission does not intend to dissolve, and might like it.

John R. Allen refers to the lack of public interest in regard to ventilating problems. I have been told that Chicago is different in this regard, in that we have more applications for lectures on heating and ventilating than we can fill. I gave nineteen myself in November and December, and two this month, and could not take care of numbers of other requests. Every woman out there is an embryo engineer and can discuss the matter of heating and ventilating with just as much fluency as any of our engineers, and lots of them know more about it. They study very carefully the problems of heating and ventilating in schools, moving picture houses and theatres, and the demands for lectures before women's clubs can hardly be filled.

Mr. Franklin suggests that every member subscribe his portion to the encyclopedia, and put his shoulder to the wheel. I have had experience in committee work and on the Chicago Commission, and while it is very nice to suggest this, it usually works out that one man on each committee does all the work. And I am very skeptical as to the results if the Society trys to get out a text-book without an editor-in-chief, who is paid a salary to devote his entire time to the work.

Out in Chicago they have started a school of heating and ventilation. They asked me to design the frontispiece for the text-book, and my contribution was the entrance to a very imposing building, over the door of which was "School of Heating and Ventilation." The first step I called "Mathematics," next "Physics," then "Mechanics," "Chemistry," "Electricity" and "Bacteriology"; in fact I did not have enough steps to name all the various branches that I felt were essential to the training of a man for this profession. One rail was "Good Judgment" and the other "Hard Work."

We find that in taking even college men in our work, we have to begin and give them instruction in all of these branches. Many of our engineers, with all the sciences that they study, do not seem to have the ability to test the plants that they have designed and installed, with even ordinary intelligence.

All of these things are important branches of heating and ventilating work, and should be included in any text-book that we put out.

J. A. DONNELLY: There is nothing more diversified in this country than the methods and kinds of education. If we attempt to reduce heating and ventilating to an exact science, and do all our educational work along these lines, we shall certainly work it into a very restricted field. The science of heating and ventilating is a peculiar one in that a man educated for it outside of actual work and experience, seldom gets any practical experience. If a man takes a course in mechanical engineering, machine design for instance, he can readily get shop practice and become familiar with the practical end of the work. This is a weak point in the training of men for our field; the common and rudimentary knowledge of the man who works at the trade is unknown to the man who has simply had a technical training.

For a number of years in the meetings of the Society, I have expressed it as my opinion that one of the first duties of the engineering profession is to provide an adequate means of education for the young man entering it, or already engaged in it. We must recognize the needs of the different men; men who estimate, design and install, and who manufacture all the appliances used in the different phases of the work all are eager for more information. In deciding how this should be provided, we find that we must meet the requirements of these different men; for some, the correspondence course is best, others can avail themselves of evening courses, and others would prefer a course of lectures more or less popular in nature.

A number of years ago there was a class conducted in plan-reading and estimating. One of the members asked the instructor how heating and ventilating apparatus was taken off, and the instructor had to confess that he did not know—it was a special line. As the result of this, some of the members took up the question with the Y. M. C. A. and they established a course in Heating and Ventilation. Such a demand existed then and it exists to-day, although the heating and ventilating engineers may not hear of it. Many of the young men who work for engineers and contractors would like such a course; others more advanced would like an opportunity of facilitating the study of the subject.

I have also found a demand in the high schools and in the higher grades of grammar schools, that the class before it leaves might have an opportunity of hearing a talk on heating and ventilating. In one of the high schools in New York, the teacher said that he found it difficult to get some one available who could give the pupils a talk on the subject and go over the apparatus in the building, so that the scholars might have some idea of how the heating and ventilating problem had been taken care of during the four years of their course. This is a field that we might well get into, and see that lecturers were available for this purpose.

I think the work of the Chicago Commission on Ventilation is a good thing, and think that we should have a New York Commission and acquaint the public with some facts. Then when they think of ventilating, they would think of the Commission and not of the man who sells them a strip of wood to put in their windows.

C. A. FULLER: This subject has been of interest to me, because as some of you know, I have been conducting a class in heating and ventilating in the evenings for several years past. I have obtained a very clear idea of where the greatest demand for this work lies, and where the most good can be done. There are two separate and distinct courses along which to work. One is a school for the advancement of scientific research work in heating and ventilating. The other is a school for uplifting the profession. The first I do not think we want; the Society itself is a school of research, and the work being done by the committees and the papers that are presented are advancing work of this kind in an admirable way.

I think the most good can be done if we get hold of young men who have had little, if any, theoretical training—men who are in heating work or in allied lines, and who have obtained what information they possess through experience and practical application. We find that such men form the larger percentage of those who are interested in evening courses. One thing that I want to impress is that if the work is to be done in this way, it must be in form. We do not want a post-graduate course of a university, but a simple elementary school of heating and ventilating.

WM. J. BALDWIN: I think that what we want is a primer on the subject, not a treatise; something that will present the work in the simplest possible form. At least we might begin in

this way and gradually develop it. It is the little things that the junior wants to know, and this training is to prepare our young men to be the engineers of the future. Most of us here can go to Kent or any of the other hand-books and find out what we want to know, because we know what we lack, or should know it.

A word to the Committee that has been appointed: There is an index in the public library that has been compiled to cover ventilating subjects—a bibliography of the subject that may help. I mention this as it may be a guide in getting some of the subject matter together so far as ventilation is concerned.

Another point to assist a committee is, if we took each subject to be treated as mentioned in the paper and had each man that feels interested on that part of the subject write about 500 words on it, we might benefit very much, and the committee would have something to start work on. This would start the work of the primer that it might afterwards be able to develop until it would become a treatise on the whole broad subject.

Perry West: I think that we all will agree that this undertaking is a most worthy one, and I think we also pretty well agree that so far as a text-book is concerned, that it will be costly, not only in money but in talent and energy. I do not understand from Prof. Kent's motion for adoption of the report and the carrying on of the work under the direction of the Council, whether that motion carries the power to solicit or raise money to publish a book. In the report that was read it is recommended that we adopt some method of underwriting the book. That means that a certain number of members can get together and raise money for the purpose themselves. I should be opposed to the motion of Prof. Kent if it carried with it any power for expending money and assuming financial obligations by the Committee. I should likewise oppose the motion if it contemplated getting money in the way suggested.

Mr. Lewis has suggested starting a fund by assessing each member $5.00. It seems to me that this book would cost more than the $2,500, which we might raise in this way, and it would be a fallacy to start something that we did not know how we are going to finish. I should say that if we are going to publish a text-book, we need more data before the Committee could go ahead with the publishing.

I also understand that it is proposed to draw from the Society the best talent available to prepare material for this book. We

need all the talent we have to carry on the work of the Societv in general, to make our meetings a success. It is hard to get men to present papers now for the Society and Chapters, and I should like to know what the Committee thinks the inducement will be for them to produce material for the book. Whenever members could be induced to contribute anything the Society has probably had the benefit of it already, and if it is available, why no edit what we have. This thing is going to run to something larger in dollars and cents, than anything we have ever done before.

As to the demand for such a book, we will agree that there is no such book, but there are publishers who publish technical books as a business, and if they have not found a demand for such a compilation, where will *we* find it? We are young compared to some of the other societies, and they have not found it expedient to start anything like this. It seems to me that this looks like something born of youth and over-enthusiasm on our part. Therefore, I am against the motion which is before us, because I feel that there are only certain phases that we might carry out to advantage. We need not wait the slow growth in some of these things that Mr. Franklin speaks of, but we should not undertake some of the things that are going to involve a great deal of expense.

D. M. QUAY: This point has been brought up, that the preparation of this book would take from the energy needed and now expended in preparing papers for the Society. A number will be just as willing to prepare articles for this Committee as for our meetings, when they are going to be used in a series of classified articles. We need such a committee to correlate and classify the articles submitted for publication. You have to go through a large number of our proceedings before you can find many subjects very conclusively treated and some are misleading to a man who is looking for information.

PRESIDENT HART: The previous question has been called for. The motion stands before you that the discussion be closed and the other motion voted upon.

Motion that discussion be closed was carried.

The motion that the report be accepted and the Committee continued, and the work referred to the incoming Council with the request that they co-operate with the Committee on the matter, was also carried.

No. 395

# REPORT OF COMMITTEE ON OPERATING COSTS OF PUBLIC BUILDINGS

Your Committee, appointed to submit report on cost of operating mechanical plants in federal buildings, would respectfully submit the following, which is made up from statistics given in the reports furnished by the Treasury Department of the United States Government through the courtesy of Mr. N. S. Thompson, a member of the Committee.

In Table 1 the items give quantities and costs for operating the several buildings, as mentioned in the Table.

Table 2 gives the statistics showing the cubical contents, area in square feet, number of employees and the quantity of electricity used for light and power in the several buildings mentioned.

Respectfully submitted,

D. M. QUAY,
N. S. THOMPSON. } COMMITTEE.

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Presented at the Annual Meeting of THE AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, New York, January, 1916.

## FEDERAL BUILDINGS

Operating Statistics.

| Building | Baltimore P.O & C.H. | Boston P.O. Sub. Tr. | Brooklyn P.O. | Chicago P.O. | Cincinnati P.O. | Detroit P.O. | Indianapolis P.O. |
|---|---|---|---|---|---|---|---|
| Boilers NO. | 5 | 8 | 3 | 5 | 6 | 8 | 4 |
| Boilers H.P. | 700 | 1000 | 900 | 1500 | 750 | 400 | .600 |
| Gen's NO. | 3 | 4 | 3 | 4 | 5 | -- | -- |
| Gen's H.P. Eng. | 507 | 480 | 280 | 980 | 675 | -- | -- |
| K.W. Gen. | 325 | 300 | 175 | 600 | 425 | -- | -- |
| Eng. NO. | -- | -- | -- | -- | -- | 2 | 1 |
| Misc. H.P. | -- | -- | -- | -- | -- | 20 | 15 |
| Steam Pumps NO. | 3 | 6 | 4 | 13 | 4 | 6 | 4 |
| Steam Pumps H.P. | 15 | 60 | 20 | 800 | 18 | 315 | 39 |
| Heat. Surf. Squ. Ft. Dir. Rad. | 20000 | 30000 | 15260 | 45000 | 60000 | 20864 | 20933 |
| Ind. Rad. | -- | -- | 5924 | 45000 | -- | 9380 | 3820 |
| Equ. Dir. | 20000 | 30000 | 33032 | 180000 | 60000 | 39624 | 32393 |
| System | Steam | Steam | Steam | Steam | Hot Water | Steam | Steam |
| Elec. Elev. Mo. | 148 | 80 | 55 | 60 | 50 | 26 | 54 |
| Power Pump. Mo. | 44 | -- | 15 | 48 | 54 | -- | 18 |
| K.W. Misc. Mo. | 41 | 80 | 25 | 580 | 36 | 19 | 60 |
| Con'd Load. | 233 | 160 | 95 | 688 | 140 | 45 | 132 |
| Max. Dem. | 60 | 84 | 35 | 140 | 51 | 15 | 50 |
| Min. Dem. | 5 | 6 | 5 | 9 | 2 | 0 | 2 |
| Elc. Lighting | 131 | 110 | 84 | 330 | 95 | 59 | 67 |
| Light Misc. | 19 | 5 | 6 | 30 | 10 | 3. | 14 |
| K.W. Cond. Load. | 150 | 115 | 90 | 360 | 105 | 62 | 81 |
| Max. Dem. | 85 | 90 | 50 | 310 | 59 | 31 | 40 |
| Min. Dem. | .10 | 26 | 11 | 33 | 19 | 4 | 8 |
| Elc. Con'd Load. | 383 | 275 | 185 | 1048 | 245 | 107 | 213 |
| Curr't. Max. Dem. | 120 | 174 | 70 | 420 | 107 | 40 | 85 |
| K.W. Min. Dem. | 15 | 32 | 16 | 42 | 21 | 4 | 10 |
| (Annual K.W.H.) | 367814 | 614987 | 385772 | 1534670 | 414250 | 94905 KWH<br>1013400 Cu.Ft. Gas | 152397 |
| Aver. Dem. | 42 | 70.2 | 44.1 | 175 | 47.3 | 10.8 KW 1160 Cu.Ft. Gas per Hr. | 17.4 |
| Contents, Cu. Ft. | | | | | | | 4215400 |
| P.O. | 3835000 | 5098100 | 3721600 | 11564000 | 7883500 | 4000000 | |
| Court House | 3006000 | | | | | | |
| Floor Area | | | | | | | 192500 |
| P.O. Squ. | 157200 | 206900 | 165000 | 760000 | 192700 | 182000 | 3047.94 |
| Court House Ft. | 149300 | | | | | | |
| Current Cost | -- | -- | -- | -- | -- | Cur. 3796.18 | 907.5 |
| | | | | | | Gas 5885.32 | 2192.38 |
| Coal per Annum Tons | 1372.164 | 3187.7 | 4487.794 | 8183.922 | 41,991.900 Cu.Ft. Gas | 1638.147 | 47607 |
| | | | | | 42.8 tons Coal | | 21.37 |
| Cost | 4361.47 | 12012.99 | 12334.34 | 24911.86 | 5576.54 | 4805.41 | |
| Water Cu. Ft. | 41630 | 1073484 | 147485 | 2032513 | 335000 | -- | 452 |
| Cost | 27.06 | 1288.17 | 1474.19 | 1067.07 | 259.69 | -- | 178.40 |
| Ash Removal Cu. Yds. | 211.42 | 906 | 2639.2 | 2013 | 7 | 521 | 101.25 |
| Cost | 105.71 | 516.42 | 1319.60 | 755.38 | 3.50 | 208.40 | 25.30 |
| Oil Gallons | 527 | 1457 | 1655.5 | 1639.5 | 1171.375 | 188.5 | 45 |
| Cost | 113.31 | 329.94 | 302.61 | 412.38 | 277.22 | 44.43 | 4.37 |
| Waste lbs. | 318 | 1519 | 806 | 2017 | 565.5 | 32.25 | |
| Cost | 30.71 | 141.50 | 77.13 | 199.14 | 54.62 | 2.90 | |
| Other Supplies | 62.69 | 82.68 | 155.47 | 2807.36 | 26.78 | 30.50 | 0.00 |
| Rep. to gen. Plant | 120.57 | 0.00 | 511.25 | 450.00 | 0.00 | 0.00 | 0.00 |
| Rep. to Boilers | 32.49 | 67.50 | 1149.47 | 95.00 | 49.90 | 0.00 | 141.48 |
| Labor | 12218.75 | 21086.25 | 18645.00 | 28457.50 | 13153.75 | 8083.13 | 5977.50 |
| Total Cost | 17072.76 | 35525.45 | 35969.06 | 59155.69 | 19402.00 | 22856.27 | 11588.74 |
| | | $5672.40 Steam sold to P. Tubes | $6464.64 Steam sold to P. Tubes | $6832.52 Steam sold to P. Tubes | | | |

## FEDERAL BUILDINGS

Operating Statistics.

| Kansas City Mo. P.O. | Milwaukee P.O. | Court New Orleans House | New York Ct. H. & P.O. | Omaha P.O. | Philadelphia Ct.H. & P.O. | Pittsburg P.O. | S. Francisco P.O. & Ct.H. | St Louis Ct.H. | S. Louis New P.O. |
|---|---|---|---|---|---|---|---|---|---|
| 6 | 8 | 2 | 4 | 5 | 5 | 4 | 5 | 5 | 4 |
| 450 | 600 | 400 | 2000 | 400 | 600 | 480 | 650 | 1000 | 600 |
| 3 | -- | 3 | 5 | -- | 4 | 3 | 4 | 4 | -- |
| 320 | -- | 320 | 833 | -- | 750 | 495 | 720 | 400 | -- |
| 200 | -- | 200 | 555 | -- | 475 | 300 | 450 | 250 | -- |
| 2 | 6 | -- | -- | -- | -- | -- | -- | -- | -- |
| 50 | 100 | -- | -- | -- | -- | -- | -- | -- | -- |
| 7 | 8 | 4 | -- | 5 | 3 | 2 | 6 | 1 | 3 |
| 84 | 330 | 20 | -- | 165 | 25 | 10 | 18 | 5 | 40 |
| 16377 | 11680 | 11526 | 21866 | 18202 | 32891 | 16480 | 9980 | 47500 | 12047 |
| 6519 | 11945 | -- | 3000 | 3324 | 8000 | 2816 | 3530 | 9000 | 10350 |
| 35934 | 47515 | 11526 | 30866 | 28174 | 56891 | 24928 | 20570 | 74500 | 43097 |
| Steam | Steam | Steam | Steam | Steam | Steam | Steam | Steam | Hot Water | Steam |
| 68 | -- | 54 | 131 | -- | 108 | 55 | 117 | 66 | 12 |
| 14 | -- | 26 | 99 | -- | 28 | -- | 33 | 6 | 25 |
| 57 | 7 | 20 | 236 | 15 | 56 | 12 | 150 | 24 | 308 |
| 139 | 7 | 100 | 466 | 15 | 192 | 67 | 300 | 96 | 345 |
| 50 | 5 | 25 | 180 | 10 | 60 | 40 | 94 | 55 | 70 |
| 2 | 0 | 2 | 5 | 0 | 10 | 5 | 5 | 0 | 4 |
| 70 | 83 | 82 | 235 | 32 | 140 | 125 | 158 | 116 | 130 |
| 7 | 9 | 18 | 30 | 4 | 4 | 5 | 7 | 10 | 20 |
| 77 | 92 | 100 | 265 | 36 | 144 | 130 | 165 | 126 | 150 |
| 40 | 40 | 65 | 222 | 18 | 116 | 60 | 135 | 82 | 94 |
| 7 | 8 | 27 | 67 | 2 | 50 | 10 | 17 | 22 | 19 |
| 216 | 99 | 200 | 731 | 51 | 336 | 197 | 465 | 222 | 495 |
| 81 | 40 | 82 | 367 | 25 | 140 | 92 | 212 | 130 | 141 |
| 9 | 8 | 31 | 77 | 2 | 60 | 15 | 22 | 22 | 23 |
| 188754 | 105020 | 441478 | 1362160 | 36649 | 700441 | 317322 | 659203 | 383761 | 512232 |
| 21.6 | 12 | 50.4 | 155.5 | 4.2 | 80 | 36.2 | 75.3 | 43.8 | 58.5 |
| 2534000 | 3877000 | 6085000 | 8334200 | 3147300 | 7378900 | 3276000 | 4166500 | 5885000 | 4764500 |
| 129000 | 183800 | 304000 | 299100 | 143600 | | | | | |
| -- | Cur. 3312.86 | | | Cur. 2028.39 | 204700 | 126000 | 216500 | 161500 | 167200 |
| | Gas 26.89 | | | Gas 78.20 | | | | | |
| 7010.73 bb Oil | 938.567 | 1353.45 | 6299.55 | 1084.053 | -- | -- | -- | -- | 9271.61 |
| 6378.39 | 3003.00 | 4724.67 | 18058.98 | 5160.10 | | | | | |
| 5363.6 | -- | 436269.43 | 1546851 | 60164.5 | 3627.98 | 39374.2 Cu ft Gas | 329073 Gal Oil | 2879.723 | 1162.779 |
| 4.31 | -- | 267.98 | 1546.85 | 89.40 | | | | | |
| | | | | | 8780.45 | 6094.57 | 6243.19 | 6093.71 | 2397.06 |
| -- | 184.25 | 200 | 2542 | 395.5 | 487409 | 391098 | 295645 | 390450 | 4861 |
| -- | 112.34 | 0.00 | 827.66 | 98.88 | 146.22 | 347.68 | 667.17 | 234.27 | 4.74 |
| 895.25 | 159 | 662 | 2197.67 | 69.375 | 1432.17 | -- | -- | 1053.8 | 279.54 |
| 245.75 | 37.12 | 169.64 | 393.19 | 22.78 | 535.66 | -- | -- | 415.62 | 113.39 |
| 206.25 | 128.375 | 210 | 1701.5 | 50 | 631.5 | 816.5 | 849.625 | 521 | 33.55 |
| 19.59 | 14.59 | 18.90 | 164.25 | 5.50 | 143.35 | 192.82 | 344.98 | 99.33 | 7.93 |
| | | | | | 1464 | 190 | 279.5 | 462 | 92 |
| | | | | | 98.82 | 17.10 | 27.95 | 42.65 | 8.28 |
| 43.96 | 23.26 | 0.90 | 265.50 | 6.38 | 113.75 | 46.09 | 297.00 | 38.50 | 37.00 |
| 36.25 | 64.20 | 188.55 | 1797.48 | 136.48 | 10.91 | 0.00 | 48.00 | 0.00 | 0.00 |
| 0.00 | 463.45 | 1345.37 | 2024.93 | 750.96 | 140.57 | 51.00 | 361.00 | 491.42 | 52.50 |
| 8663.75 | 6763.75 | 10228.75 | 30090.00 | 6493.75 | 18437.50 | 7963.75 | 13385.00 | 16570.00 | 9671.25 |
| 15392.00 | 13821.46 | 16944.76 | 55168.84 | 14870.82 | 28407.23 | 14713.01 | 21374.29 | 23985.50 | 21563.76 |
| | | | $5624.64 Steam sold to P Tubes | | | | | $3688.42 Steam sold to P Tubes | |

## FEDERAL BUILDINGS

*Operating Characteristics*

| Building Name | Contents Cu. Ft. | Area Sq. Ft. | Sq. Ft. Per Employee | Lighting K.W. Connected | Lighting K.W. Demand | Lighting K.W.H. Per Annum | Power Motor H.P. Connected | Power K.W. Demand | Power K.W.H. Per Annum |
|---|---|---|---|---|---|---|---|---|---|
| Chicago P.O. | 11564000 | 760000 | 157 | 360 | 310 | 1200000 | 925 | 140 | 335000 |
| Cincinnati P.O. | 7883500 | 192700 | 377 | 105 | 59 | 305000 | 188 | 51 | 109000 |
| Phila. P.O. | 7378900 | 204700 | 137 | 144 | 116 | 570000 | 257 | 60 | 130000 |
| New York C.H. | 8334200 | 299100 | 146 | 265 | 222 | 989000 | 625 | 180 | 343000 |
| St. Louis | 5885000 | 161500 | 130 | 126 | 82 | 360000 | 128 | 55 | 24000 |
| Buffalo P.O. | 5052000 | 209960 | 265 | 96 | 60 | 209000 | 188 | 50 | 9500 |
| Jacksonville Fla. P.O. | 1114000 | 44383 | 184 | 24.1 | — — | 44282 | 25 | — — | 9260 |
| Topeka Kan. P.O. | 1090000 | 33718 | 212 | 20.2 | — — | 21902 | 20 | — — | 1560 |
| St. Joseph Mo. P.O. | 1068000 | 35833 | 278 | 14.5 | — — | 13381 | 17 | — — | 2223 |
| Cedar Rapids Io. P.O. | 1061000 | 32950 | 407 | 23.8 | — — | 24280 | 20 | — — | 1349 |
| Ft. Worth Tex. P.O. | 1028000 | 19200 | 116 | 11.0 | — — | 20093 | 38 | — — | 11250 |
| Chattanooga Tenn. P.O. | 1025000 | 31345 | 281 | 12.5 | — — | 30080 | 16 | — — | 2640 |
| San Antonio Tex. P.O. | 1016000 | 38461 | 240 | 20.0 | — — | 16685 | 16 | — — | 4129 |
| Mobile, Ala. Cu. H. | 1010000 | 34090 | 324 | 10.4 | — — | 20267 | 17 | — — | 3530 |
| Galveston Tex. P.O. | 1007000 | 31640 | 520 | 10.7 | — — | 18950 | 16 | — — | 4030 |
| Wheeling W.V. P.O. | 980000 | 39710 | 270 | 21.0 | — — | 27414 | 33 | — — | 3847 |
| Peoria Ills. P.O. | 977000 | 46660 | 305 | 35.0 | — — | 24561 | 20 | — — | 3142 |
| Columbia S.C. P.O. | 522000 | 16830 | 168 | 14.6 | — — | 14220 | — — | — — | — — |
| Rock Island Ills. P.O. | 518000 | 27870 | 246 | 11.8 | — — | 11711 | 30 | — — | 2400 |
| Ft. Dodge Io. P.O. | 515000 | 23030 | 420 | 10.7 | — — | 4302 | — — | — — | — — |
| Lexington Ky. P.O. | 515000 | 21760 | 265 | 9.9 | — — | 20268 | — — | — — | — — |
| Boise Idao P.O. | 510000 | 25120 | 261 | 13.3 | — — | 11362 | 20 | — — | 2776 |
| Harrisburg Pa. P.O. | 507000 | 18230 | 186 | 13.9 | — — | 20135 | 15 | — — | 3027 |
| Pensacola Fla. P.O. | 506000 | 19500 | 315 | 8.0 | — — | 12499 | 15 | — — | 2205 |
| Jackson Miss. P.O. | 505000 | 29500 | 506 | 9.0 | — — | 12823 | $2\frac{1}{2}$ | — — | 1563 |
| Greensboro N.C. P.O. | 505000 | 18030 | 286 | 4.5 | — — | 12108 | $\frac{1}{2}$‖ | — — | 385 |
| Leavenworth Kan. P.O. | 504000 | 24600 | 464 | 5.5 | — — | 12511 | $\frac{1}{2}$‖ | — — | 95 |
| Fargo N.D. P.O. | 503000 | 16321 | 224 | 8.3 | — — | 9395 | 16 | — — | 781 |
| Asheville N.C. P.O. | 496000 | 20965 | 354 | 11.3 | — — | 7164 | — — | — — | — — |
| Burlington Vt. P.O. | 495000 | 22600 | 323 | 11.5 | — — | 7204 | 20 | — — | 120 |
| Kokomo N.D. P.O. | 253000 | 9980 | 256 | 4.4 | — — | 3034 | — — | — — | — — |
| Petersburg Va. P.O. | 253000 | 8220 | 175 | 6.9 | — — | 5843 | — — | — — | — — |
| Pine Bluff Ark. P.O. | 251000 | 9000 | 200 | 4.4 | — — | 7142 | $\frac{1}{2}$‖ | — — | 168 |
| Ithaca N.Y. P.O. | 251000 | 9635 | 240 | 4.5 | — — | 4862 | — — | — — | — — |
| Bloomington Ill. P.O. | 250000 | 10030 | 208 | 4.7 | — — | 11569 | — — | — — | — — |
| New Albany Ind. P.O. | 249000 | 11434 | 326 | 2.2 | — — | 4051 | — — | — — | — — |
| Athens O. P.O. | 249000 | 15300 | 570 | 5.5 | — — | 5582 | — — | — — | — — |
| Monroe La. P.O. | 248000 | 6734 | 354 | 6.3 | — — | 5347 | — — | — — | — — |
| Meadville Pa. P.O. | 247000 | 12020 | 316 | 9.0 | — — | 7798 | — — | — — | — — |
| Muncie Ind. P.O. | 246000 | 7000 | 132 | 3.4 | — — | 5367 | $\frac{1}{3}$‖ | — — | 126 |

‖ Cancelling Machine Motor

## DISCUSSION

R. P. Bolton: I think the material in this paper is worth some good discussion. The costs of operation of heating and ventilating plants in public buildings is a subject of interest in itself, and in particular because these data deal with Federal buildings, which are in a class by themselves.

It is always interesting to compare the cost of fuel with the cost of labor. Observations in commercial buildings of similar character, show that there is a definite relation between the cost of labor and fuel. This is not a fixed relation, but it will be found that in commercial buildings, economically operated, the labor cost will closely approach the coal cost; when they are very economically operated, the labor will be less than the coal. In municipal buildings it is usually the other way around. Fuel is less costly than the labor.

If the investigations along this line can be extended, as I hope they can be, and other buildings included, this comparison may be better brought out. This matter is so expansive that it is impossible to do anything but call attention to the salient features.

President Kimball: I wish to offer a word of explanation. The collection of these data was not a matter of days but of years. It occurred to me some time ago that it would be desirable if we could have some data of this nature, but I did not think at the time we would get so much of it as we have. I think we might well consider that we have made a good start upon the collection of data on a subject which is a hard one to do anything with, and I think we are to be congratulated on the good start we have made.

We have appointed other committees to report further on this subject. We hope to have more reports submitting data on this and other classes of buildings.

R. P. Bolton: I should like to draw the attention of the members to the addendum, which is very interesting.

In regard to the selling of steam for various purposes in these buildings, it is very ingenious, I think. The company that looks after the operation of the pneumatic tubes service charges so much for its service, and the United States charges them with the steam for operating the pumps for the service. They take their money out of one pocket and put it in another.

No. 396

# OPERATING COSTS OF HEATING AND VENTILATING AND POWER PLANTS IN HOSPITALS

Your committee has collected and tabulated data from seven hospitals on the cost of operation of their heating, ventilating and power plants. The fuel consumed and oil and waste used, however, cover not only that required for the heating and ventilation, but also that for lighting, power, refrigeration, kitchen, laundry, sterilizers, hot water service, etc. None of the hospitals are provided with means for ascertaining the distribution of steam to the various uses. Hospital "A" has a meter on the feed water line and one on the hot water heating system. Hospital "D" has a meter on the feed water line.

It should be noted that in buildings "D" and "F" the coal consumption would have been somewhat higher if ice were made on the premises, and in building "E" if both ice were made and electric current generated. All the figures, therefore, should be considered with these points in view.

From the analysis of the data it would appear unquestionably that Hospital "A" has the most economical plant—the coal consumption being the lowest, compared with the others, if based on the number of tons and annual cost per one million cu. ft. of building, notwithstanding that it has the largest amount of radiation.

It is safe to assume that the factors contributing to this economy are as follows:

1. One pipe riser down feed hot water heating with recording and integrating meter and recording thermometers on the flow and return, enabling the regulation of the heating of the buildings from one central point—in the power house, and thus preventing waste usually accompanied with individual control of

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Presented at the Annual Meeting of The American Society of Heating and Ventilating Engineers, New York, January, 1916.

COLLECTED AND COLLATED BY A. M. FELDMAN AND C. E. PEARCE.

| HOSPITAL BUILDING. | LOCATION | CUBIC FEET OF BUILDING. | NUMBER OF PATIENTS | TOTAL RADIATION. | | VENTILATION. | | HEATING. | BOILERS. | | COST OF HEAT. & VENTIL. INCLUDING BOILERS, PUMPS, & PIPING IN POWER PLANT, LAUNDRY, KITCHEN STERILIZERS IN DOLLARS | | COAL. USED FOR GENERATING STEAM FOR ALL PURPOSES, INCLUDING HEATING, VENTILATING, LIGHTING, POWER, LAUNDRY, KITCHEN, STERILIZERS, HOT-WATER SERVICE AND REFRIGERATION. | | | | | | | ANNUAL COST OF LABOR: ENGINEERS, FIREMEN, OILERS, COAL-PASSERS, STEAM-FITTERS, HELPERS. DOLLARS. | ANNUAL COST OF OIL, GREASE AND WASTE. DOLLARS. | ANNUAL COST OF COAL, LABOR, OIL AND WASTE. DOLLARS. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | DIRECT. SQ. FT. | INDIRECT. SQ. FT. | SUPPLY AND EXH. FANS. | ASPIRATION | | KIND & NUMBER OF UNITS | TOTAL HORSE POWER | TOTAL | PER CU. FT. | KIND | COST PER GROSS TON AT BUILDING DOLLARS | NUMBER GROSS TONS USED PER YEAR. | TOTAL ANNUAL COST DOLLARS | NUMBER OF TONS PER YEAR PER ONE MILLION CU. FT. | ANNUAL COST PER ONE MILLION CU. FT. DOLLARS. | ANNUAL COST PER PATIENT. DOLLARS | | | TOTAL. | PER ONE MILLION CU. FT. | PER PATIENT. |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| A | NEW YORK | 5,400,000. | 450. | 50,560 | 4818. | EXHAUST FANS ONLY IN KITCHEN, LAUNDRY, [illegible] | YES. | HOT-WATER FORCED CIRCULATION | FOUR WATER TUBE, STOKERS. | 1000 | 136,850. | .025 | MIXTURE. 2 PARTS BITUMINOUS SLACK 1 PART ANTHRACITE [illegible] | [illegible] | 3,730 | 4,017. | 690.74 | 2595.74 | 31.15 | 7092. | 274. | 21,383. | 3959.81 | 47.51 |
| B | NEW YORK | 5,793,600. | 500. | 40,500 | 6710. | SUPPLY AND EXHAUST. | NONE | STEAM TWO-PIPE VACUUM. | SIX FIRE RETURN TUBULAR. | 900. | 225,000. | .039 | #2 BUCKWHEAT. | 3.30 | 6,460 | 21,318. | 1115.14 | 3680.00 | 42.64 | 6744. | 400. | 28,462. | 4913.16 | 56.92 |
| C | PITTSBURGH | 3,338,000. | 500. | 15,800 | 6337. | SUPPLY AND EXHAUST. | NONE | STEAM TWO-PIPE VACUUM. | THREE WATER TUBE, STOKERS & FORCED DRAFT | 531. | 104,705. | .031 | BITUMINOUS SLACK | *1.75 | 4,350 | 8,526 | 1303.17 | *2554.22 | *17.05 | 5280. | 256. | *14,062. | *4212.70 | *28.12 |
| D | NEW YORK | 2,096,000 | 225. | 13,375 | 4610. | SUPPLY AND EXHAUST | NONE | STEAM TWO-PIPE VACUUM. | FOUR FIRE RETURN TUBULAR | 440. | 86,461. | .041 | #2 BUCKWHEAT. | 3.47 | 2,437 | 8,459 | 1162.7 | 4035.78 | 37.60 | 5500. | 486. | 14,445. | 6891.70 | 64.20 |
| E | NEW YORK | 1,406,400. | 232 | 17,000 | NONE | NONE | NONE | STEAM ONE-PIPE GRAVITY. | TWO WATER TUBE. | | 30,000. | .021 | MIXTURE 2 PARTS BARLEY 1 PART BITUMINOUS. | 3.10 / 4.20 | *2,100. | 5,419 | 1493.17 | *3853.10 | *23.36 | 4020. | 78 | 9,517. | 6766.92 | *41.02 |
| | | | | | | | | | | | | | | ← DOES NOT INCLUDE LIGHTING AND POWER. → | | | | | | | | | | |
| F | NEW YORK | 1,345,815. | 150 | 9,000 | 3000 | NONE | NONE | STEAM TWO-PIPE VACUUM. | TWO WATER TUBE. | 264. | 48,595 | .036 | MIXTURE 2 PARTS BARLEY 1 PART BITUMINOUS | 3.34 | 2,035 | 6,797 | 1512.09 | 5050.47 | 45.31 | 5515. WITHOUT [illegible] | 223 | 12,535. | 9314.07 | 83.56 |
| G | BUFFALO. | 756,355. | 150 | | | NONE | NONE | STEAM TWO-PIPE GRAVITY. | TWO FIRE RETURN TUBULAR. | 160. | 26,452 | .035 | SMOKELESS BITUMINOUS. | *2.85 | 1,071. | 3,053 | 1416.00 | *4036.46 | *20.35 | 3600. | 75(?) | 6,728. | 8895.29 | *44.85 |

A—Hydraulic plunger elevators; electric storage battery carries all night lighting load in summer; utilizing warmed condensing water from absorption refrigerating machine.

B—Absorption refrigerating machine.

C—*Note lower price of coal in Pittsburgh.

D—Fractional admission valves on radiators; utilizing warmed condensing water from absorption refrigerating machine; ice cost $790.

E—*Buy electric current at an annual cost of $5,730; $24.70 per patient; ice costs $970; $3.30 per patient.

F—Buy ice at cost of $1,100; just installed compression ice making machine; indirect radiation not used.

G—*Note lower price of coal in Buffalo.

radiators. In the latter case as a rule radiators are not shut off, but windows are thrown open. The use of smaller sizes of piping than with low pressure steam, also effects reduction of radiation losses.

2. Of the New York hospital plants this is the only one where automatic stokers and smokeless furnaces are installed enabling the use of bituminous slack coal.

3. The installation of an overhead coal weighing scale and a recording, registering and integrating meter on the feed water.

4. The installation of high efficiency Corliss four valve high speed engines for the generation of the electric current.

5. The installation of an electric storage battery which takes care of the all night lighting load in summer.

6. The installation of hydraulic plunger elevators with high efficiency simplex compound pumps, which start and stop automatically with the starting and stopping of the elevators, whereas in all the other hospital buildings electric elevators are in use, for which large generating units must run constantly and most of the time with low load factors.

7. An efficient proportion of boiler units; one boiler carries the summer load, two are operated during the winter months, a third boiler is thrown in when the outdoor temperature drops to 10 deg. fahr. or below, and a fourth boiler is kept in reserve, thus enabling the boilers to be maintained in good condition.

8. The installation of more efficient simplex pumps instead of duplex on the feed water, circulation and ammonia.

9. Absorption system of refrigeration where the use of live steam is a minimum.

10. The water which is used in the condenser and all other parts of the refrigerating machine comes out quite warm. Instead of wasting it as is done in practically all other plants, here it is collected in an open tank and pumped through a heater for use in the laundry, thus recovering a great deal of the heat used in the generator of the refrigerating machine.

11. This plant is also equipped with a recording boiler steam pressure gauge and a graphic recording flue gas thermometer, as a guide for the fireman and as a means for the engineer to watch the latter.

13. A great deal of credit is due to the ability and zeal of the chief engineer of the plant who carefully examines the various recording charts and holds his men to account. The men also work with great interest on account of the shorter hours;

they work on a three shift schedule, ten hours a shift overlapping each other two hours, during which time the retiring gang works on keeping up the plant, as packing pumps, inspecting traps, etc.

In conclusion we want to state that the operating engineers of all the other plants observed by us are trying their level best to reduce the coal consumption by the installation of undergrate turbo-blowers and are burning the cheaper grades of anthracite with an admixture of one-quarter of bituminous slack.

Respectfully submitted,

A. M. FELDMAN, }
C. E. PEARCE, } COMMITTEE.

## DISCUSSION

R. P. Bolton: I think we should offer our thanks to Mr. Feldman for the figures he has collected and presented to us on a class of buildings upon which very little authentic information is available, for information on hospitals is very scarce indeed. He has also been able to give observations on buildings located in various territories, which is much better than having all observations based on one territory. The remarks that Mr. Feldman has made do not, in view of their modesty, acquaint you with the fact that he is responsible in a great measure for the economical operation that he shows in plant "A." He should receive a great deal of credit for this work.

Some of the points brought out are in some ways similar or parallel to those that we referred to in the previous report, such as comparative costs of labor and fuel. A continuance of these reports should lead us to the further study of other buildings, and we shall continue to find that these are the two important features that should be considered. It will take a great deal of study and time to bring out clearly all the points of comparison. I think that we are to be congratulated in having a member like Mr. Feldman who is not only able to collect this information but willing to give it to us.

James C. Goodrich (chief engineer of the Montefiore Home): The plant of the Montefiore Home was operated last year and this year under different conditions. This year I am using a different coal, lower B.t.u. efficiency, but my crew is trained well, and the year previous they were green. We have cleaner boilers and less loss of steam. Our evaporation is slightly lower, 9.62 against 10.04, but we are not wasting anything.

Henry C. Meyer, Jr.: I do not wish to criticise, but it does not seem to me that you can arrive at a conclusion unless you know just what work has been done. I think Mr. Feldman could add to the good work he has done, by giving us some information about elevators, amount of heat required, the amount of electricity used outside of elevator requirements, and similar work. If it is possible to get this information, I think it would add greatly to the value of the report.

No. 397

# THE ESTABLISHMENT OF STANDARD HEATING ELEMENTS FOR COOKING APPARATUS WITH SPECIAL REFERENCE TO LOW PRESSURE STEAM*

By Davis S. Boyden, Boston, Mass. (Member)

Assisted by J. W. Wattles, F. L. Richards and A. H. Boynton

THE following series of tests are an extended study of the characteristics of steam cooking apparatus, which it is hoped the Society will continue, so as to develop, if possible, cooking apparatus that will operate on low pressure steam and hence be suitable for connection to the steam mains of the central heating companies.

Tests on the compartment steamer were given in Vol. XX of the Transactions of the Society for 1914, page 421.

The tests which follow were made on standard representative cooking apparatus loaned by the makers for this purpose. The following is a list of the apparatus tested giving sizes or capacities.

*Full Jacketed Cast Iron Kettle*:

10 gallon capacity, without cover.

*Half Jacketed Cast Iron Kettle*:

40 gallons capacity, with cover.

*Cast Iron Kettle With Submerged Annular Heating Element Cast in Bottom of the Kettle*:

35 gallon capacity, with cover.

*Dish Warmer*:

Interior dimensions, 5 ft. 6 in. by 1 ft. 9 in. equals 51.33 cu. ft.

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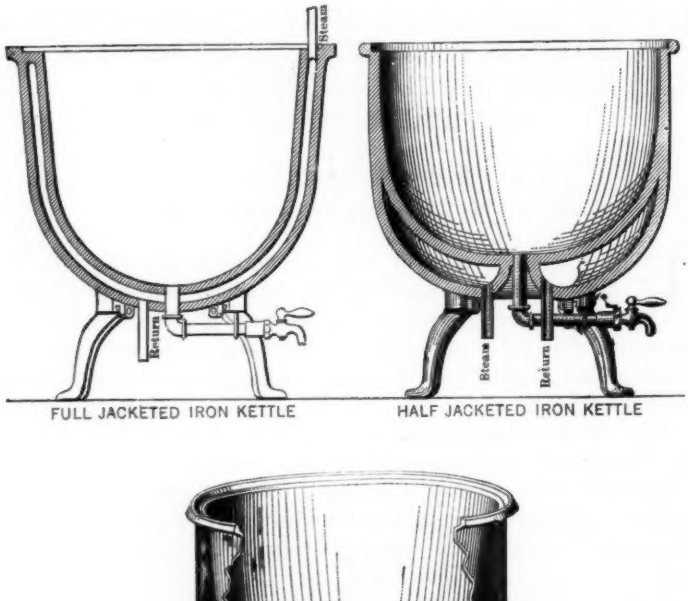
* This paper is part of a report of the joint educational committee of the National District Heating Association and this Society read at the annual convention of the Association in Chicago, June, 1915.

Presented at the Annual Meeting of The American Society of Heating and Ventilating Engineers, New York, January, 1916.

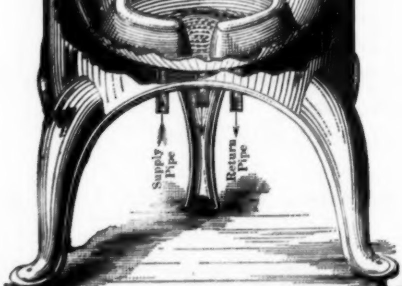
Heating element equals 91 ft. of ¾-in. iron pipe equally divided among three shelves; four pipes under each.
Radiation equals 25.02 sq. ft.

*Steam Table*:

Bath dimensions 3 ft. 3 in. by 1 ft. 9 in. by 5 in.
Heating element equals 1 coil of 4 ft. 6 in. of ½-in. iron.
Radiation equals 0.99 sq. ft.




FULL JACKETED IRON KETTLE HALF JACKETED IRON KETTLE




SECTIONAL VIEW

FIG. 1. DETAILS OF KETTLES TESTED.

Fittings:

1 pan, 2 qt. size (21 in. by 12 in.)
2 pans, 1 qt. size (8½ in. by 4 in.)

Openings for

4 pots, 4 qt. size (8½ in. diam.)
Pots were not used in tests.

*Hot Water Urn*:

Vertical, syphon type. 8 gallon capacity.
Heating element equals coil 7 ft. 3 in. of ⅞ in. brass tubing.
Radiation equals 1.66 sq. ft.
In a second series of tests the coil was increased to 14 ft. 6 in. of ⅞-in. brass pipe having 3.32 sq. ft. of radiation.

The required steam pressure for the tests was obtained through a reducing valve from a main carrying steam at about 80 lbs. pressure. The steam was then taken through a cooling coil to reduce the super-heat and used in the apparatus being tested. The pressure and temperature of the steam was measured before entering the apparatus. At the lowest point of the supply connection a drip valve was installed and run partly open to remove any condensation in the supply pipe.

The return from the apparatus tested was discharged by a ½-in. Thermograde valve, acting as a thermostatic trap, passed through a small cast iron radiator to condense any vapor caused by re-evaporation, and then measured by a small Simplex condensation meter.

The typical arrangement of the supply and return connections showing locations of valves, steam gauge, thermometers, cooling coil, meter, etc., is shown in Fig. 2.

The principal object of the tests was to find the rate of heating, the pounds of steam required to boil or reach a maximum temperature, the rate of condensation to maintain boiling or maximum temperature, and the lowest steam pressure it would be advisable to use with each piece of apparatus in commercial work.

Steam pressures of 2, 5, 10, 15 and 25 lbs. were used in the tests.

In all tests, the water in the kettles and other apparatus at the start of the tests was at 60 degrees F.

The temperature of the testing room was from 85 degrees to 90 degrees during the tests.

Observations of steam pressure, temperature, etc., were taken at five minute intervals during the tests except some of the

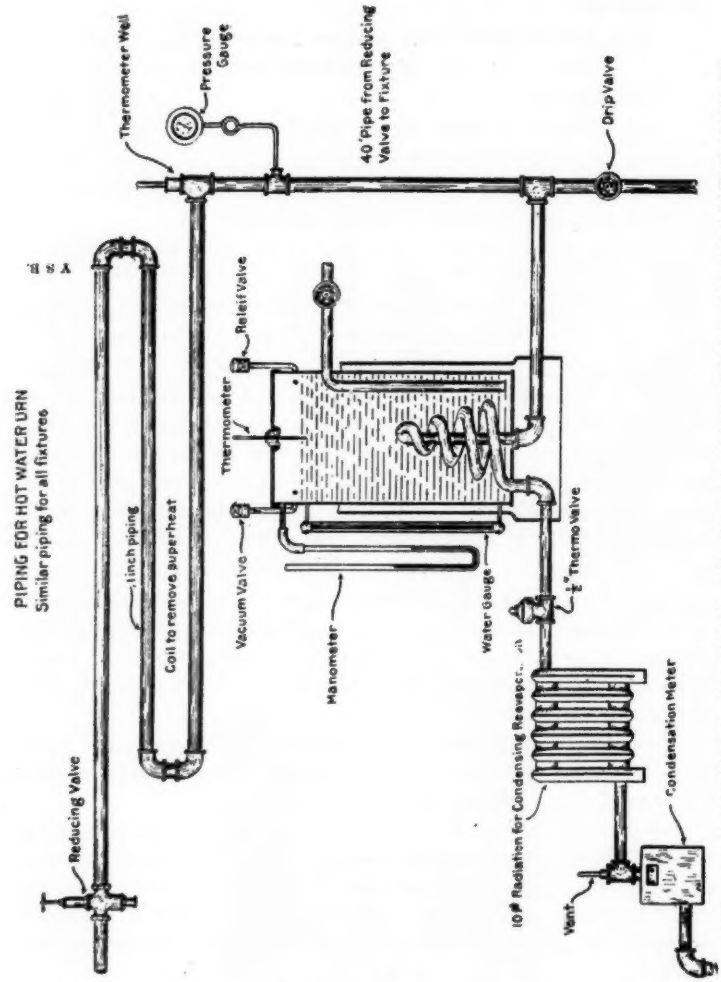



FIG. 2. ARRANGEMENT OF SUPPLY AND RETURN CONNECTIONS AND APPARATUS USED IN CONDUCTING TESTS.

tests on the hot water urn, where one minute readings were taken.

One degree and two degrees superheat in the steam supplied to the apparatus was obtained at times, but all the results are calculated on the basis of dry steam.

The full jacketed and half jacketed kettles were tested without covers, while in commercial use they are always installed with covers. This should be kept in mind when interpreting

the results of the tests, for if covers had been used the kettles would have heated up in less time.

The kettle with annular heating element was furnished with a cover and was tested both with cover open and with cover closed.

The hot water urn was first tested with the regular heating element, consisting of a coil of 7 ft. 3 in. of ⅞-in. brass tubing. The heating element as then replaced by one double in size, consisting of a coil of 14 ft. 6 in. of ⅞-in. brass tubing. Pressures in the water space of the urn were measured by a mercury manometer. Temperatures of the water up to about 200 degrees were taken by a thermometer immersed directly in the water; above 200 degrees the temperatures were taken by a thermometer in a deep oil well immersed in the water and screwed in the cap on the top of the urn. It was found that a pressure of 6½ in. of mercury was needed for the relief valve to blow and that a pressure of 1½ in. of mercury was sufficient to syphon the urn.

The steam table was tested with water in the bath and in the pans.

No dishes were available to place in the dish warmer, so it was tested without them. Tests were made with doors open and with doors closed. Temperatures were taken at the top and bottom of the heated space.

A summary of the tests on the different apparatus and plots showing graphically the rise in temperature and the steam consumption of the tests on the kettles are given herewith. It should be noted that the column marked "Efficiency to the Boiling Point," shows the percentage that the heat gained in the water heater bears to the heat of the steam used to bring the water to the boiling point.

It should be noted that water was used in these tests of cooking apparatus; while in actual commercial use the cooking materials and liquids used would somewhat increase the boiling point and the time necessary to bring to boiling.

These tests would seem to indicate:

(1) That the full jacketed kettle should work satisfactorily on 5 to 10 lbs. steam pressure.

(2) That the half jacketed kettle is unsuitable for low steam pressures and requires 15 lbs. pressure or over.

(3) The kettle with submerged annular heating element is the most efficient and requires 5 to 10 lbs. steam pressure. If

the heating element were increased, the kettle would operate under the most favorable conditions on 2 lbs. pressure.

(4) The importance of having covers on the kettles is clearly shown from the tests on the kettle with annular heating element where, with 5 lbs. pressure, with cover on, it boiled in 68 minutes; while with cover off it only reached 202 degrees in 85 minutes.

(5) The dish warmer and steam table are suitable for low steam pressure and should operate satisfactorily at 2 to 5 lbs. pressure. For 2 lbs. pressure it would be advisable to increase the heating element somewhat.

(6) The hot water urn of the syphon type, with standard coil, requires 5 lbs. steam pressure. For 2 lbs. pressure the surface in the coil should be increased and it would be best to use the open, elevated type of urn, so that the hot water could flow out by gravity without having to form a pressure in the urn.

In conclusion it may be said that all the cooking apparatus tested, with the exception of the kettles, are readily adapted to low pressure steam, even as low as 2 lbs. Kettles are not suitable for operation on very low steam pressure and it would seem as though a complete new design or, at least, considerable changes in the present designs would be necessary for successful use with 2 lbs. steam pressure. The importance of proper supply and return piping is apparent when using low steam pressures and the same care and attention to sizes, drainage, etc., should be followed as in low pressure steam heating practice. Supply pipes should be large, each piece of apparatus should have a separate trap or thermostatic return valve, and the return piping should drain free and clear into an open return with no chance of back pressure.

SUMMARY OF TESTS ON STEAM COOKING APPARATUS

*Full Jacketed Kettle*

(No Cover)

| Steam Press. | Steam Temp. | Time to Boil. | Steam Used to Boil. | Steam per hr. to Maintain Max. or Boiling Temps. | Eff. to Boiling Point. | Water Heated. |
|---|---|---|---|---|---|---|
| 2 lbs. | 220° | (202° in 65 min.) | 26 lbs. | 15 lbs. | ...... | 8 gals. |
| 5 lbs. | 228° | 50 min. | 30 lbs. | 26 lbs. | ...... | 8 gals. |
| 10 lbs. | 241° | 22 min. | 19 lbs. | 30 lbs. | 45.6% | 8 gals. |
| 25 lbs. | 268° | 13½ min. | 20 lbs. | 63 lbs. | 43.3% | 8 gals. |

*Half Jacketed Kettle.*

(No. Cover)

| | | | | | | |
|---|---|---|---|---|---|---|
| 5 lbs. | 228° | (195° in 65 min.) | 41 lbs. | 16 lbs. | ...... | 15 gals. |
| 15 lbs. | 252° | 105 min. | 76 lbs. | 24 lbs. | 35.7% | 25 gals. |

*Kettle With Submerged Annular Heating Element.*

(With Cover on)

| | | | | | | |
|---|---|---|---|---|---|---|
| 2 lbs. | 220° | (200° in 90 min.) | 42 lbs. | 11 lbs. | ...... | 25 gals. |
| 5 lbs. | 228° | 68 min. | 43 lbs. | 22 lbs. | 63.6% | 25 gals. |
| 10 lbs. | 248° | 48 min. | 42 lbs. | 41 lbs. | 64.9% | 25 gals. |
| 15 lbs. | 252° | 36 min. | 40 lbs. | 55½ lbs. | 67.9% | 25 gals. |
| 2 lbs. | 220° | (200° in 75 min.) | 37 lbs. | 14½ lbs. | ...... | 15 gals. |
| 5 lbs. | 229° | 45 min. | 38 lbs. | 14 lbs. | 72 % | 15 gals. |

*Same Kettle.*

(With Cover Off)

| | | | | | | |
|---|---|---|---|---|---|---|
| 5 lbs. | 229° | (202° in 85 min.) | 56 lbs. | 27 lbs. | ...... | 25 gals. |

*Dish Warmer*

(With Doors Closed)

| Steam Press. | Steam Temp. | Time to Max. Temp. | Temp. Top | Temp. Bottom | Steam Used | Steam per hr. to Maintain Max. Temp. |
|---|---|---|---|---|---|---|
| 2 lbs. | 220° | 30 min. | 150° | 148° | 8 lbs. | 15 lbs. |

(Same with Doors Open)

| | | | | | | |
|---|---|---|---|---|---|---|
| 2 lbs. | 220° | 25 min. | 114° | 112° | 8 lbs. | 14 lbs. |

*Steam Table.*

(With 12 gals. of Water in Bath)

| Steam Press. | Steam Temp. | Time to Boil in Bath | Steam Used to Boil | Temp. in Pans | Seam per hr. to Maintain Max. Temp. or Boil |
|---|---|---|---|---|---|
| 2 lbs. | 219° | 196° in 50 min. | 26 lbs. | 166° | 14 lbs. |
| 5 lbs. | 228° | 45 min. | 24 lbs. | 180° | 20½ lbs. |

*Hot Water Urn.*

(With Standard Coil)

| Steam Press. | Steam Temp. | Time to Heat to 212° | Steam Used to Heat to 212° | Eff. to 212° | Time to Obtain 2" Hg. Press | Time to Blow Relief Valve | Max. Press. Obtain'd in in. of Hg. | Steam per hr. to Maintain Max. Press. | Water Heated |
|---|---|---|---|---|---|---|---|---|---|
| 5 lbs. | .... | 13 min. | 10 lbs. | ...... | 14 m. | ..... | ..... | 10.3 lbs. | 7 gals. |
| 10 lbs. | .... | 7 min. | 10 lbs. | ...... | 7⅓ m. | ..... | ..... | 40 lbs. | 7 gals. |
| 15 lbs. | .... | 5 min. | 10 lbs. | ...... | 5 m. | ..... | ..... | 75 lbs. | 7 gals. |
| 25 lbs. | .... | 3 min. | 10 lbs. | ...... | 3 m. | ..... | ..... | Boiled too hard. | 7 gals. |

(With Large Coil)

| | | | | | Time to Obtain 1¾" Hg. Press. | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2 lbs. | 220° | 14 min. | 10 lbs. | 76.9% | 35 m. | ..... | 1¼" | 13 lbs. | 7 gals. |
| 5 lbs. | 230° | 8 min. | 10 lbs. | 76.6% | 9 m. | 11 m. | 4½" | 25 lbs. | 7 gals. |
| 10 lbs. | 220° | 5 min. | 12 lbs. | 63.7% | 5½ m. | 6 m. | 6⅛" | 57 lbs. | 7 gals. |
| 15 lbs. | 252° | 4 min. | 10 lbs. | 76.1% | 4 m. | 4½ m. | 6½" | 75 lbs. | 7 gals. |
| 25 lbs. | 267° | 3 min. | 10 lbs. | 75.8% | 3 m. | 3½ m. | 14 " | 138½ lbs. | 7 gals. |

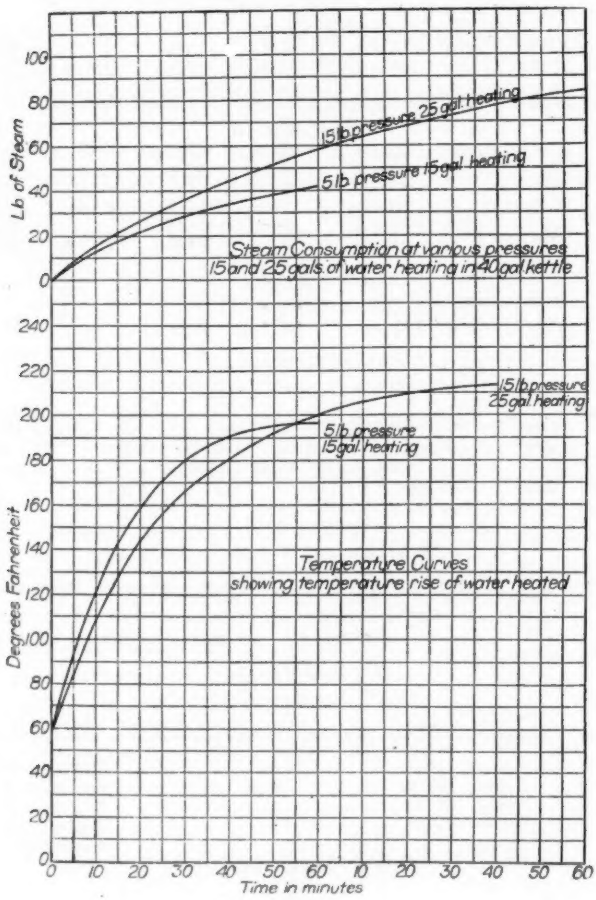



FIG. 3. RESULTS WITH HALF JACKETED IRON KETTLE.

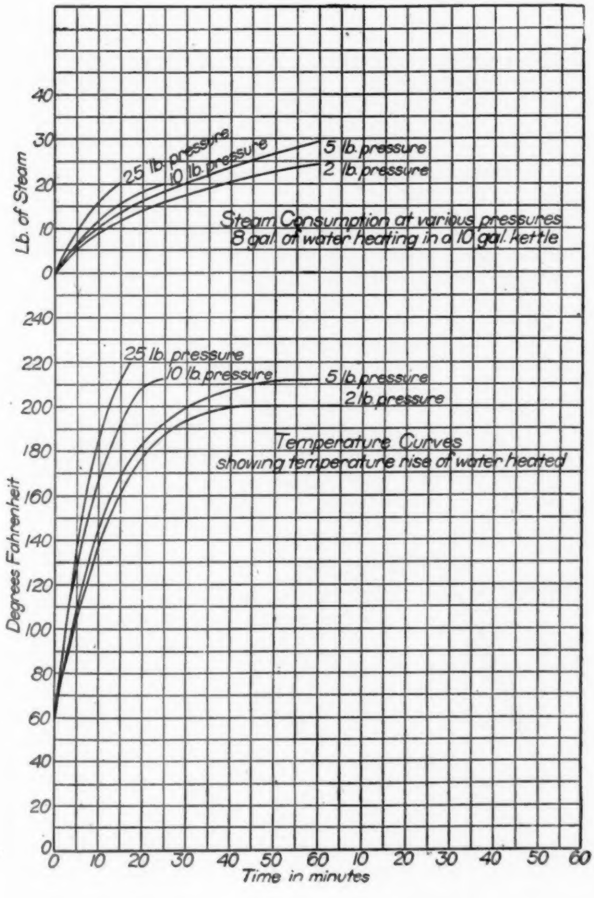



FIG. 4. RESULTS WITH FULL JACKETED IRON KETTLE.

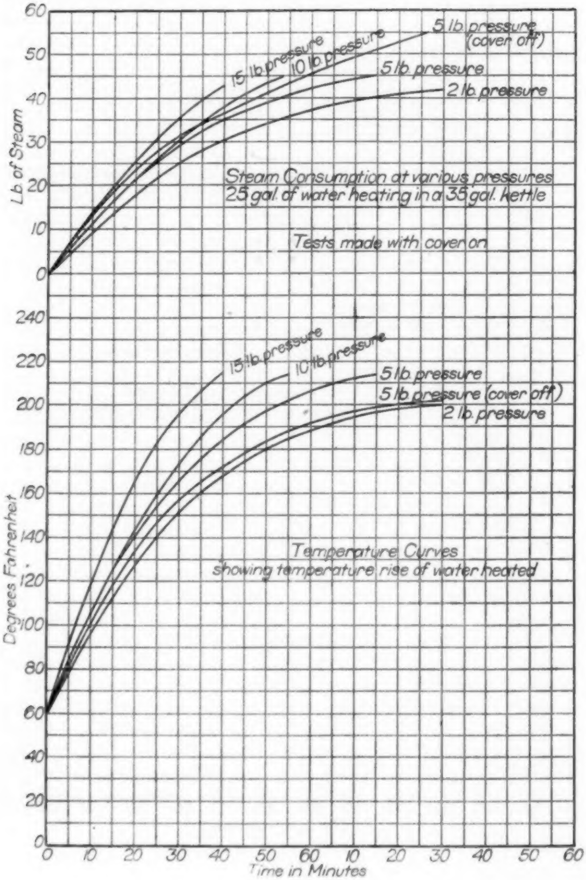



FIG 5. RESULTS WITH COVERED IRON KETTLE WITH SUBMERGED HEATING ELEMENT (25 GAL. OF WATER).

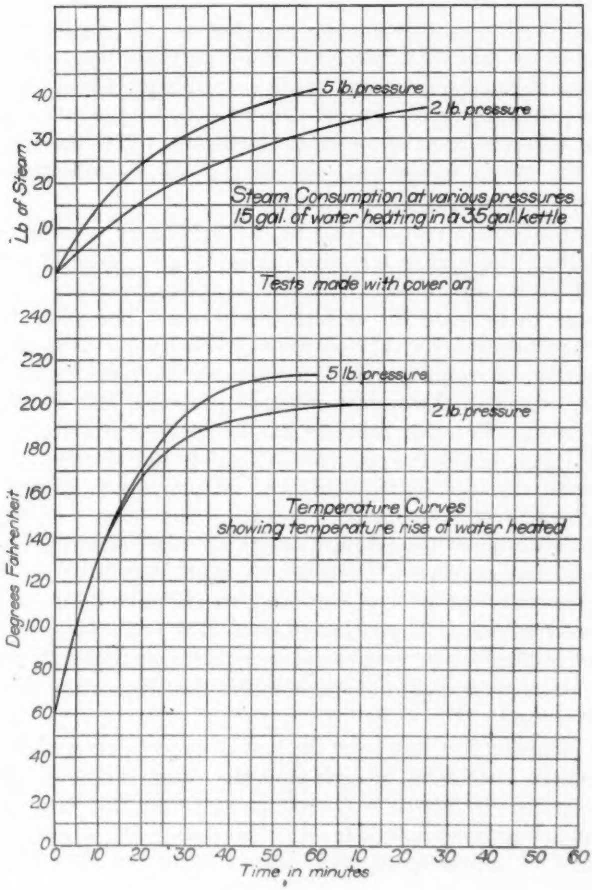



FIG 6. RESULTS WITH COVERED IRON KETTLE WITH SUBMERGED HEATING ELEMENT (15 GAL. OF WATER).

## DISCUSSION

D. S. Boyden: I should like to add that it is surprising how little interest and knowledge the manufacturers have of the steam element in their apparatus. They spend a great deal of trouble and time, as well as money, in finishing with nickel-plate, adding to the ornaments, etc., but we are unable to get them to co-operate with us toward the collection of any information as to steam requirements of their apparatus. About all the attention they pay to the steam element is to have a steam-fitter the last thing before the apparatus goes out, put a coil or two in for the steam connection, and that is all the attention the steam end of the apparatus receives.

I want to call attention also to the haphazard method used in installing the piping for steam cooking apparatus in hotels, hospitals, restaurants, etc. There is no selection of the kind of apparatus to be used for certain conditions. The same apparatus may be used on various pressures from 30 to 80 lb. In the heating of buildings, it is customary to reduce the high pressure steam to the lowest constant pressure, and we obtain good results. But this practice has never been applied to the use of steam cooking apparatus. I think the Society should work with the idea of requiring the manufacturers to put out better steam elements in their cooking apparatus. A fixture should be designed for efficient operation at a certain pressure, and be plainly marked—"Designed to work at 2 lb., 5 lb., 8 lb., steam pressure," as the case may require, and then limit the user to those conditions. If you take a chef used to working with 80 lb. pressure, he won't be able to use the same apparatus with 60 lb., hence we should have a standard heating element for all apparatus.

The manufacturer has been the last to become interested, but I have been successful in obtaining the co-operation of one of these concerns in Boston. We are going to try this year to get more manufacturers interested in this work. We should have this class of apparatus as well defined as we do electrical apparatus.

There are many things that we do with electricity in 20 minutes that could be done in 5, but the maximum demand would be greater and the difference in time does not warrant the increased speed, and more time could be allowed when using low pressure steam for cooking if the operators were educated to the conditions.

I trust that the members of this Society will use every effort when they come in contact with the manufacturer or user of cooking apparatus, to bring about a more scientific design and classification of this apparatus.

M. WILLIAM EHRLICH: It might be of interest to know that the art of cooking by low-pressure steam was known to some even in 1792. Even though the science was not mastered, the practice was understood. This is simply given as a historical fact and is based on an advertisement shown to me by R. P. Bolton as appearing in an English newspaper of that date. The advertiser was a dealer in kitchen utensils and appliances.

PRESIDENT KIMBALL: This is a question that is always one of difficulty in institutional work. There is necessity of varying pressures from 40 to 70 lb., all of which must be available at the same time, and it complicates matters considerably.

M. W. FRANKLIN: This subject is a very wide one. The use of steam for cooking is not confined to cooking food—it is also used largely in chemical plants. It is a fact that the apparatus used in this industry is widely diversified, and very little has been done toward standardizing any of it.

The Society would be engaged in an excellent work if it would accomplish the standardization of the apparatus among the many manufacturers. Candy manufacturers, people working with glue, etc., have long used steam for cooking, but it is a curious fact that none of the apparatus made by the different manufacturers is subject to any standard practice. It is very difficult for an engineer to design a plant, for instance, a chemical works, and be able to get just what he wants. The different makers will not have the complete line of apparatus that is needed, and while one type will be very suitable in one respect, another type will be better for another use, and it is not easy to find all the apparatus that will be needed, so that it will fit together advantageously.

No. 398

# COST OF REMOVING AND REPLACING PAVEMENTS INCIDENT TO THE INSTALLING OF HEATING LINES IN CITY STREETS

By W. F. Verner, Ann Arbor, Mich.

Member

ONE of the principal factors to be considered in constructing a distribution system for heating relates to the tearing up of the pavements in the city streets, and replacing the same in good condition. In most cities permission must first be granted before construction is begun, and in many cities it is customary for the municipality to do all repairing relative to the streets, and bill the company installing the system for the labor and material expense, incident to the repaving over the mains and services.

The manner pursued in constructing the system plays an important part. The customers must first be secured before extending a line, and after a period of years it is found that the total cost of construction is more than if the system had all been put in at once. That is, the work is done piecemeal. The cost of removing and replacing the pavement per square yard is necessarily higher than what a contractor would charge if he were paving an entire street. The following tables are the results of an extended study of actual costs.

TABLE 1—COST OF REMOVING PAVEMENT

| | Sq. yd. removed per day of 9 hr. per man | Cost per sq. yd. |
|---|---|---|
| Sheet Asphalt | 13.05 | .24 |
| Brick | 16.83 | .18 |
| Concrete foundation | 16.11 | .19 |
| Cedar Block, Creosoted Block and Cobblestone | 27.00 | .12 |
| Granite Block | 14.04 | .22 |

Presented at the Annual Meeting of The American Society of Heating and Ventilating Engineers, New York, January, 1916.

The gangs doing this work generally consist of 6 men and a foreman; laborers, \$2.50 per day; foreman, \$3.60 per day of 9 hours. Distributing the foreman's time to each laborer will make a charge of \$3.10 for the work accomplished by each laborer.

The above costs are used in preparing Table 2.

TABLE 2—COST TO REMOVE VARIOUS KINDS OF PAVEMENT PER LINEAL FOOT OF TRENCH

| Width of Trench | Sheet Asphalt on 6" Concrete | Brick on 6" Concrete | Cedar Block on 6" Concrete | Cedar Block on Sand | Concrete 6" | Creosoted Block on 6" Concrete | Granite Block on 6" Concrete | Cobblestone on Sand |
|---|---|---|---|---|---|---|---|---|
| 22" | .09 | .09 | .06 | .03 | .03 | .07 | .10 | .03 |
| 23" | .09 | .09 | .07 | .03 | .04 | .07 | .11 | .03 |
| 24" | .10 | .10 | .07 | .03 | .04 | .07 | .11 | .03 |
| 25" | .10 | .10 | .07 | .03 | .04 | .08 | .11 | .03 |
| 26" | .10 | .10 | .08 | .04 | .04 | .08 | .12 | .03 |
| 27" | .11 | .10 | .08 | .04 | .04 | .08 | .12 | .03 |
| 28" | .11 | .11 | .08 | .04 | .04 | .09 | .12 | .03 |
| 29" | .12 | .11 | .08 | .04 | .05 | .09 | .13 | .04 |
| 30" | .12 | .11 | .08 | .04 | .05 | .09 | .13 | .04 |
| 31" | .12 | .12 | .09 | .04 | .05 | .09 | .13 | .04 |
| 35" | .14 | .13 | .10 | .04 | .05 | .10 | .14 | .04 |
| 36" | .14 | .13 | .10 | .04 | .06 | .10 | .15 | .04 |
| 37" | .14 | .13 | .10 | .05 | .06 | .11 | .15 | .04 |
| 39" | .14 | .14 | .11 | .05 | .06 | .12 | .16 | .05 |
| 41" | .15 | .15 | .11 | .05 | .06 | .12 | .16 | .05 |

TABLE 3—HOURS LABOR AND MATERIAL QUANTITIES FOR REPAIRING PAVEMENTS, UNITS PER SQUARE YARD (All old material is used where possible)

| | Brick on 6" Concrete | Cedar Block on 6" Concrete | Cobblestone on Sand | Granite Block on 6" Concrete | Creosoted Block on 6" Concrete | Concrete 6" | Cedar Block on Sand |
|---|---|---|---|---|---|---|---|
| Foreman's time (hrs.) | .36 | .80 | .18 | .34 | .36 | .31 | .11 |
| Pavers' time (hrs.) | .66 | .90 | .44 | .55 | .85 | .76 | .33 |
| Laborers' time (hrs.) | 1.89 | 1.10 | .67 | 1.53 | 2.01 | 2.43 | .75 |
| Team time (hrs.) | .75 | 1.10 | .44 | .63 | .88 | .64 | .33 |
| Cu. ft. of sand | 1.18 | 1.50 | 1.11 | 1.20 | 1.08 | 1.68 | .76 |
| Sacks of cement | .43 | .30 | .. | .60 | .43 | .66 | .03 |
| Gallons of tar | 1.11 | .. | .. | .. | .72 | .. | .18 |
| Brick No. 1 | 3.89 | .. | .. | .. | .. | .. | .25 |
| Brick No. 2 | 1.65 | .. | .. | .. | .. | .. | .. |
| Sq. yds. cedar block, No. 2 | .. | .65 | .41 | .. | .. | .. | .. |
| Sq. yds. creosoted block, No. 1 | .. | .. | .. | .. | .24 | .. | .. |
| Sq. yds. granite block | .. | .. | .. | .. | .. | .10 | .. |
| Cu. ft. crushed stone | .09 | .. | .. | .06 | .06 | .. | .. |
| Cu. ft. of gravel | .. | .20 | .67 | .. | .. | .. | .. |
| Gallons of oil | .01 | .. | .. | .01 | .01 | .29 | .. |
| Lumber F. B. M. | .. | .. | .. | .. | .. | .. | .. |
| Spikes | .. | .. | .. | .. | .. | .. | .. |
| Total number of yards averaged | 2187.5 | 10.0 | 13.5 | 685.5 | 301.0 | 95.0 | 127.0 |

## REPAIRING ASPHALT

(Cost per Sq. Yd.)

A flat rate for repairing asphalt, not including foundation, is $1.50.

A 6" concrete foundation will cost approximately the same as concrete pavement, or $1.54 per sq. yd.

## REPAIRING BRICK PAVEMENT ON 6" CONCRETE

(Cost per Sq. Yd.)

| | | | | | | |
|---|---|---|---|---|---|---|
| Foreman | .36 | hrs. | @ | .50 | .18 | |
| Paver | .66 | hrs. | @ | .40 | .26 | |
| Laborer | 1.89 | hrs. | @ | .25 | .48 | |
| Team | .75 | hrs. | @ | .44 | .33 | |
| | | | | | | 1.25 |
| | | | 15% | | | .19 |
| | | | | | | 1.44 |
| Sand | 1.18 | cu. ft | @ | .06 | .07 | |
| Cement | .43 | sacks | @ | .40 | .17 | |
| Tar | 1.11 | gals. | @ | .12½ | .14 | |
| Brick, No. 1 | 3.89 | | @ | 25.00 | .10 | |
| Brick, No. 2 | 1.65 | | @ | 18.00 | .03 | |
| Crushed Stone | .09 | cu. ft. | @ | .05 | .004 | |
| Oil | .01 | gal. | @ | .08 | .001 | .51 |
| | | | Total | | | 1.95 |

## REPAIRING CEDAR BLOCK ON 6" CONCRETE

(Cost per Sq. Yd.)

| | | | | | | |
|---|---|---|---|---|---|---|
| Foreman | .80 | hrs. | @ | .50 | .40 | |
| Paver | .90 | hrs. | @ | .40 | .36 | |
| Laborer | 1.10 | hrs. | @ | .25 | .28 | |
| Team | 1.10 | hrs. | @ | .44 | .48 | |
| | | | | | | 1.52 |
| | | | 15% | | | .23 |
| | | | | | | 1.75 |
| Sand | 1.50 | cu. ft. | @ | .06 | .09 | |
| Gravel | .20 | cu. ft. | @ | .06 | .01 | |
| Cement | .30 | sack | @ | .40 | .12 | |
| Cedar Block, No. 2 | .65 | sq. yds. | @ | .38 | .25 | .47 |
| | | | Total | | | 2.22 |

## REPAIRING CEDAR BLOCK ON SAND

(Cost per Sq. Yd.)

| | | | | | | |
|---|---|---|---|---|---|---|
| Foreman | .18 | hrs. | @ | .50 | .09 | |
| Paver | .44 | hrs. | @ | .40 | .18 | |
| Laborer | .67 | hrs. | @ | .25 | .17 | |
| Team | .44 | hrs. | @ | .44 | .19 | |
| | | | | | | .63 |
| | | | 15% | | | .09 |
| | | | | | | .72 |
| Sand | 1.11 | cu. ft. | @ | .06 | .07 | |
| Gravel | .67 | cu. ft. | @ | .06 | .04 | |
| Cedar Block, No. 2 | .41 | sq. yds. | @ | .38 | .16 | .27 |
| | | | Total | | | .99 |

## REPAIRING CONCRETE 6″

(Cost per Sq. Yd.)

| | | | | | |
|---|---|---|---|---|---|
| Foreman | .34 | @ | .50 | .17 | |
| Paver | .55 | @ | .40 | .22 | |
| Laborer | 1.53 | @ | .25 | .38 | |
| Team | .63 | @ | .44 | .28 | |
| | | | | | 1.05 |
| | | 15% | | | .16 |
| | | | | | 1.21 |
| Sand | 1.20 cu. ft. | @ | .06 | .07 | |
| Cement | .60 sacks | @ | .40 | .24 | |
| Lumber | .36 F. B. M. | @ | 35.00 | .01 | |
| Crushed Stone | .06 cu. ft. | @ | .05 | .003 | |
| Spikes | .03 lbs. | @ | .02 | .001 | |
| Oil | .01 gals. | @ | .08 | .001 | .33 |
| | | Total | | | 1.54 |

## REPAIRING CREOSOTED BLOCK ON 6″ CONCRETE

(Cost per Sq. Yd.)

| | | | | | |
|---|---|---|---|---|---|
| Foreman | .36 hrs. | @ | .50 | .18 | |
| Paver | .85 hrs. | @ | .40 | .34 | |
| Laborer | 2.01 hrs. | @ | .25 | .50 | |
| Team | .88 hrs. | @ | .44 | .39 | |
| | | | | | 1.41 |
| | | 15% | | | .21 |
| | | | | | 1.62 |
| Sand | 1.08 cu. ft. | @ | .06 | .06 | |
| Cement | .43 sacks | @ | .40 | .17 | |
| Tar | .72 gals. | @ | .12½ | .09 | |
| Creosote Block, No. 1 | .24 sq. yds. | @ | 2.00 | .48 | |
| Crushed Stone | .06 cu. ft. | @ | .05 | .003 | |
| Oil | .01 gals. | @ | .08 | .001 | .80 |
| | | Total | | | 2.42 |

## REPAIRING GRANITE BLOCK ON 6″ CONCRETE

(Cost per Sq. Yd.)

| | | | | | |
|---|---|---|---|---|---|
| Foreman | .31 hrs. | @ | .50 | .16 | |
| Paver | .76 hrs. | @ | .40 | .30 | |
| Laborer | 2.43 hrs. | @ | .25 | .61 | |
| Team | .64 hrs. | @ | .44 | .28 | |
| | | | | | 1.35 |
| | | 15% | | | .20 |
| | | | | | 1.55 |
| Sand | 1.68 cu. ft. | @ | .06 | .10 | |
| Cement | .66 sacks | @ | .40 | .26 | |
| Granite Block | .10 sq. yds. | @ | 2.35 | .24 | |
| Oil | .29 gals. | @ | .08 | .02 | .62 |
| | | Total | | | 2.17 |

## REPAIRING COBBLE PAVEMENT ON SAND

(Cost per Sq. Yd.)

| | | | | |
|---|---|---|---|---|
| Foreman ................ | .11 hrs. | @ .50 | .06 | |
| Paver .................. | .33 hrs. | @ .40 | .13 | |
| Laborer ................ | .75 hrs. | @ .25 | .19 | |
| Team ................... | .33 hrs. | @ .44 | .14 | |
| | | | —— | .52 |
| | | 15% ................ | | .08 |
| | | | | —— |
| | | | | .60 |
| Sand ................... | .76 cu. ft. | @ .06 | .05 | |
| Cement ................. | .03 sacks | @ .40 | .01 | |
| Tar .................... | .18 gals. | @ .12½ | .02 | |
| Brick .................. | .25 | @ 25.00 per M | .01 | .09 |
| | | | —— | —— |
| | | Total ................ | | .69 |

Using the above costs per square yard for the various pavements, Table 4 is compiled.

TABLE 4—COST TO REPLACE VARIOUS KINDS OF PAVEMENT PER LINEAL FOOT OF TRENCH

| Width of Trench | Sheet Asphalt on 6" Concrete | Brick on 6" Concrete | Cedar Block on 6" Concrete | Cedar Block on Sand | Concrete 6" | Creosoted Block on 6" Concrete | Granite Block on 6" Concrete | Cobblestone on Sand |
|---|---|---|---|---|---|---|---|---|
| 22" | .62 | .60 | .58 | .26 | .28 | .75 | .67 | .17 |
| 23" | .65 | .62 | .60 | .27 | .29 | .77 | .69 | .17 |
| 24" | .65 | .62 | .62 | .28 | .29 | .77 | .69 | .18 |
| 25" | .68 | .64 | .62 | .28 | .31 | .80 | .72 | .18 |
| 26" | .71 | .66 | .64 | .29 | .32 | .82 | .74 | .19 |
| 27" | .74 | .68 | .67 | .30 | .34 | .85 | .76 | .19 |
| 28" | .77 | .70 | .69 | .31 | .35 | .86 | .78 | .20 |
| 29" | .80 | .72 | .71 | .32 | .37 | .90 | .80 | .21 |
| 30" | .80 | .72 | .71 | .32 | .37 | .90 | .80 | .21 |
| 31" | .83 | .74 | .73 | .33 | .38 | .92 | .82 | .22 |
| 35" | .94 | .80 | .80 | .36 | .43 | .99 | .89 | .24 |
| 37" | .99 | .83 | .84 | .38 | .46 | 1.04 | .93 | .25 |
| 39" | 1.03 | .87 | .89 | .40 | .49 | 1.09 | .98 | .26 |
| 41" | 1.08 | .89 | .91 | .41 | .51 | 1.11 | 1.00 | .28 |

## DISCUSSION

D. S. BOYDEN: In the larger cities, including Boston, where I am somewhat familiar with the work, the Public Service Companies are obliged to give a blanket order each year to the city and agree to pay the outside dimension of all the amounts on which permits are taken. The city takes the orders and gives them to the company with whom they have made the contract in advance for resurfacing. The city sees that the surface is put back to conform with the original surface. Much undue criticism is thrust upon the utility companies in cases of unsatisfactory resurfacing, but it occurs to me that when the company foots the bills, they should have the privilege of participating in the measurement and inspection of resurfacing inasmuch as they are held responsible by the public.

No. 399

# HEATING AND VENTILATING PLANT, WAITE HIGH SCHOOL, TOLEDO, OHIO

By Samuel R. Lewis, Chicago, Ill.

Member

THE purpose of this paper is to describe the equipment of this plant in its general arrangement, especially in the particulars which have developed in our experience with some twenty Toledo schools.

The building is of fireproof construction throughout and is, with its duplicate, the Scott High School, so located on a large campus that a detached boiler-house is impracticable. The only basement provided is for the mechanical equipment; the ground, first and second floors covering the entire area, with a refectory, kitchen, printing shop and photographic gallery on the third floor at the center.

The boiler plant is under the center of the building with its floor about 20 ft. below grade. The fuel storage of 700 tons of bituminous coal is entirely below grade, filled through manholes in a paved driveway above the bunkers. Ashes are removed by an electric elevator, and steel ash cans are used exclusively in this function, being designed especially to fit trucks. Coal is handled by a narrow gauge railway, which runs over a scale into and through the center of the coal bunkers. This railway also runs on the elevator, and is available for handling heavy machinery in the plant, as well as for the mechanical laboratory, the only educational room on the boiler floor level.

The general scheme of heating is as follows:

The heating and ventilating plants are combined, and no direct radiators are used except for special rooms. The fresh air, entering at the second floor level (since no satisfactory grade level intake, away from the danger of dust from coal handling, was

Presented at the Annual Meeting of The American Society of Heating and Ventilating Engineers, New York, January, 1916.

available) is tempered at that level, and space for a future air washer is there provided. At present, high pressure steam jets automatically controlled, are used for humidifying, with reasonably satisfactory results. The air, at about 70°, is then drawn down about fifty feet to the two supply fans, and by them forced through the distributing ducts. These are in general of masonry and at the beginning are each about 8 feet square.

At various locations convenient to the vertical flues, the distributed heating radiation is placed in plenum chambers, so that the mixing damper in each flue may receive either hot air or tempered air. The purpose of this distributed heating radiation, which comprises about one-third of the total blast surface, is to insure quick and evenly balanced distribution of the warmed air, and to give gravity heating when the fans are not in operation.

It is also arranged in this way so that various departments may be heated and ventilated, or not, as the uses of the building may require. Thus, the laboratory group, the night school group, the gymnasium, the manual training group, or the auditorium, may be separately heated and ventilated, or any of them may be closed off while the balance are in use. This is accomplished from the engine room by pneumatic control from a central indicating switchboard.

Another advantage gained by the group arrangement is that should a cold wind come from any special direction, which always means lower heating of the rooms on that side, the power of the entire plant may be diverted there, when warming the building prior to occupancy, by a simple switch manipulation from the engine room. Dampers, switch operated, are placed in the tempered air openings to all plenum chambers, independent of all thermostatic or manual control, which, prior to occupancy, insure that the slowest room to heat in that group shall cumulatively receive the heating power delivered to the entire group.

The entire air delivering system is accessible through large doors; is thoroughly lighted; and is provided with flushing valves and screwed shut sewer connections, so that it may be thoroughly washed free from dust. There is no harbor anywhere for rodents, as all pipes, conduits, etc., pass through lighted and accessible ways made for the purpose.

The air, regulated in temperature by the thermostats placed in the rooms, and controlled in volume by dampers handled by concealed chains from the rooms, passes up the vertical masonry flues and is delivered into the class-rooms about eight feet above

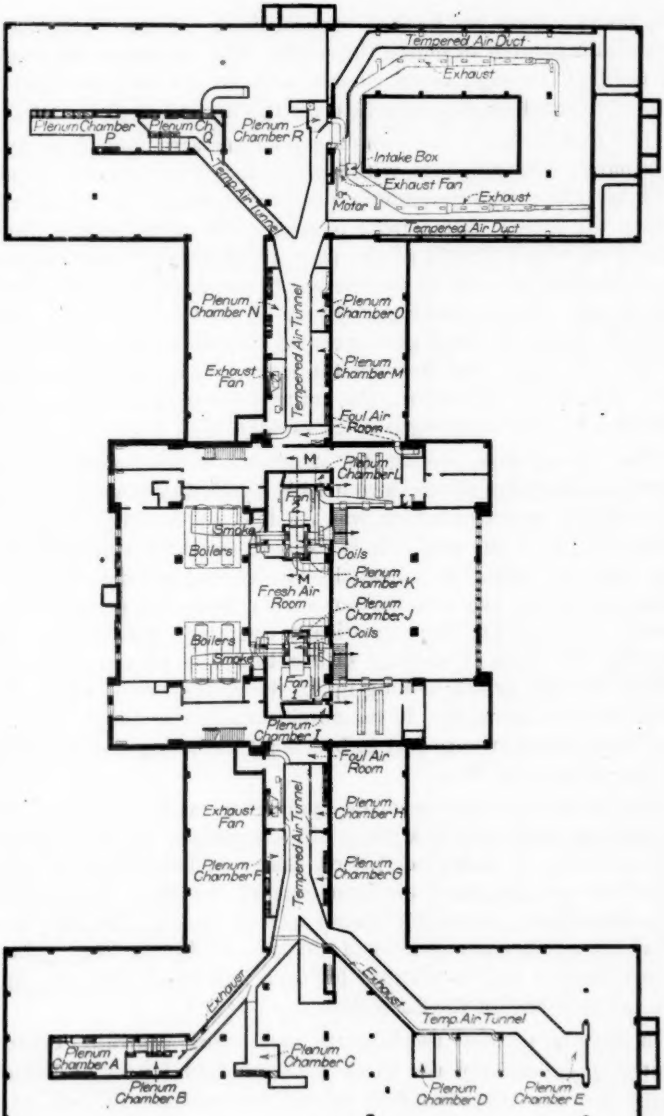



FIG. 1. BASEMENT PLAN OF THE SCHOOL, SHOWING ARRANGEMENT OF HEATING PLANT, DUCTS AND PLENUM CHAMBERS.

the floors. Here are located vertical blade adjustable diffusers, which are painted to match the walls. The air leaves the rooms at the floor through metal elbows, without screens, arranged so that they must be cleaned whenever the floors are cleaned.

The gymnasium and swimming pool are arranged to be used alternately by both sexes, with isolated locker and shower rooms. The air enters the swimming pool from the visitors' galleries above the locker rooms from tempered air inlets behind direct radiators, which permit of the easy attainment of any temperature required, as well as for the use of the room when the main supply fans are not running. The air leaves the pool-room under positive exhaust, through concealed sound-proof flues to the locker rooms, and out through the lockers to a separate exhaust fan. By this arrangement, the entire department is kept sweet smelling and the clothing is dried rapidly.

The gymnasium, owing to structural requirements, forms rather a difficult problem since neither upward or downward ventilation, nor direct radiation was feasible. It has no ceiling but that formed by the roof. It is exposed on three sides and has glass tile skylights. It is heated by individual groups of indirect radiation at the bases of the ten supply flues, the steam supply valves of which are thermostatically operated, and even in cold weather the room is warmed satisfactorily by gravity. The air enters through grilles looking up, in the window sills, and leaves the room through grilles in the outside walls near the floor, passing down about twenty feet to basement gathering ducts leading to two large vent flues.

The auditorium balances the gymnasium at the opposite end of the building, and has three sides exposed. Since it has a ceiling, however, and a bowl floor, the problem was much easier of solution. Tempered air from one of the main supply fans passes through a heating chamber to four mixing dampers, each of which supplies one-quarter of the space under the floor. There is one damper and thermostat for each half of the balcony, and one for each half of the main floor.

In addition to these thermostats, three more, centrally located, control progressively the three superimposed layers of heater. There are one thousand floor inlets, one under each seat, of a special patented type which permits of minute adjustment while preventing absolutely any dirt from entering the air chamber. The air leaves the room through the ceiling, in plaster grilles and has a separate exit from the building, due to a fire wall.

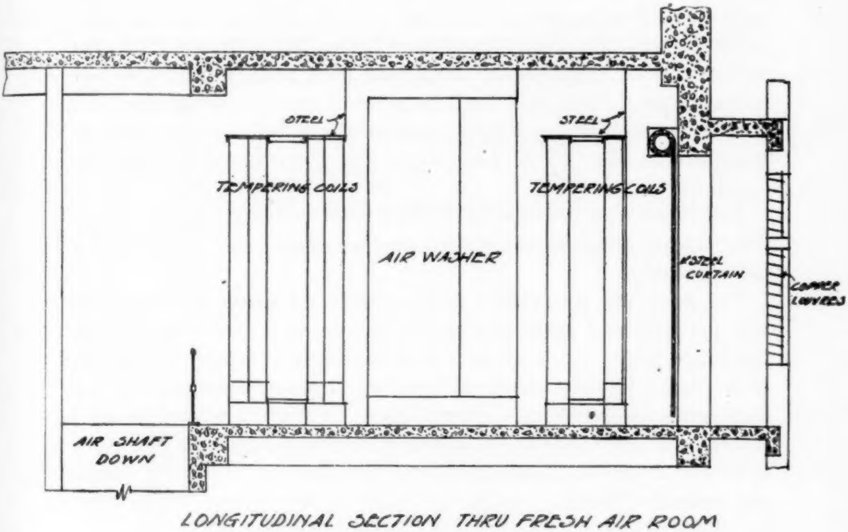



FIG. 2. DETAILS OF FRESH AIR INTAKE.

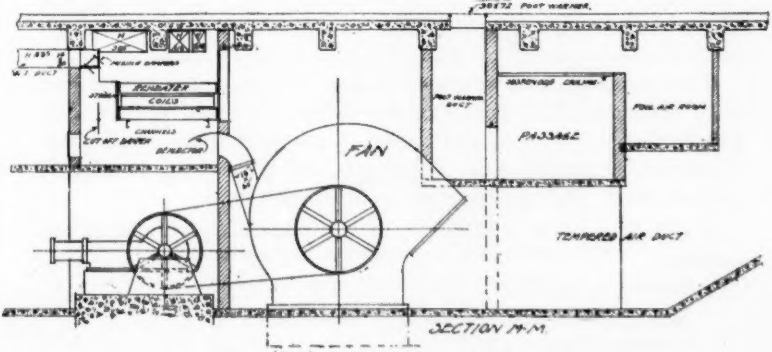



FIG. 3. SECTION M-M THROUGH FAN ROOM.

All toilet fixtures throughout the building and all lockers are positively ventilated by exhaust fans. The closets and urinals have large local vents, and the air for ventilating them is originally forced into the corridors. From the corridors, on the various floors, sound-proof individual flues supply the air to the toilet rooms. Thus the corridors receive suction ventilation, and still there is always a greater suction in the toilet rooms than in the corridors, so that no toilet room odors can possibly enter the building.

The chemical laboratory is equipped with a special phosphor-bronze exhaust fan placed in the room and controlled by the instructor.

The refectory is supplied from a central heating chamber and has an individual cut-out switch as this room is used only during the lunch hour. It is ventilated exclusively through the double doors to the kitchen, where a large exhaust fan, controlled by the occupants, is placed above the range. This arrangement is used when cooking is in progress and is effective. As the refectory is also used for entertainments, arrangements are made for standard ventilation outlets in the side walls at the floors. These must be closed when the kitchen exhaust fan is operated.

The general air from the building is discharged through two large brick chimneys. The toilet and locker exhaust fans discharge through two smaller chimneys. There are several concealed ventilators from other fans, fireplaces, forges, etc.

Steam is generated to about 90 lbs. maximum pressure in four 150 horse-power watertube boilers, provided with hand-fired brick arch furnaces. The brick settings are steel jacketed. The chimneys are 110 feet high. It has been found easy to maintain the steam pressure using three boilers, in the coldest weather, though to do so undoubtedly involves a considerable overload.

The apparatus was designed with a view to compactness and easy operation. To that end the boilers, engines, pumps, and auxiliaries, are all grouped within a comparatively small area. Space and connections are left nearby for the future installation of two 125 K. W. steam-driven generators.

The following is a schedule of the size of the principal apparatus:

Boilers, 4, 150 H. P.
Supply Fans, 2, double No. 16 Multivane.
Exhaust Fans:
  Toilets, 2, single No. 9 Multivane.
  Pool, 1, single No. 7 Multivane.

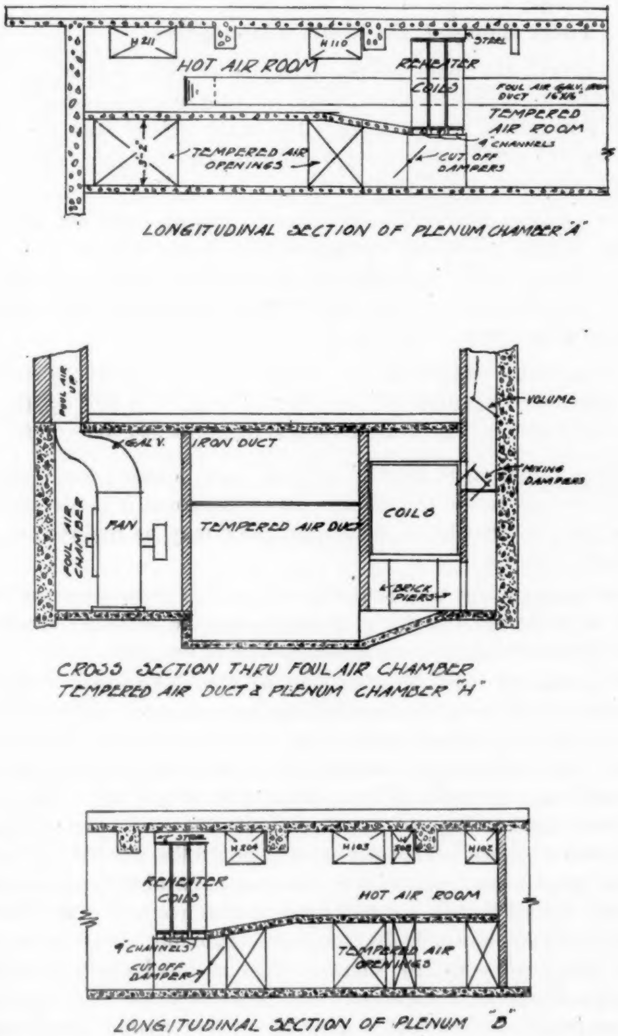



FIG. 4. DETAILS OF DUCTS AND PLENUM CHAMBERS.

**Kitchen,** 1, single No. 7 Multivane.
**Chemical,** 1, single No. 3 Multivane.
**Forge,** 1, single 60-inch steel plate.
**Forge supply,** 1, single No. 5 Monogram.

All except the main supply fans are electric driven, as they are to be used independent of the heating system and are scattered throughout the building. The main supply fans are operated by 14" x 14" belted steam engines, and for this reason are placed adjacent to the boiler-room.

The vacuum and boiler feed pumps are in duplicate and are steam driven. The air compressor is steam driven, and furnishes air at 80 lbs. pressure for laboratory purposes, as well as at 15 lbs. pressure for the temperature regulation and damper operating functions.

| | |
|---|---|
| Total blast radiation.................. | 14,029 sq. ft. |
| Total direct radiation ................. | 4,500 sq. ft. |
| Total contents of heated spaces........ | 2,900,000 cu. ft. |

Direct radiation is used in all toilet and locker rooms, in the shower rooms and in the offices. In toilet rooms, it is placed near the ceiling so that an unobstructed floor may be maintained for sanitary reasons.

The house water and that for the pool is heated by a closed feed water heater operating at high pressure, with an auxiliary direct injection noiseless circulating nozzle in the pool.

The building was completed about November 1913. It was operated throughout the entire heating season of 1914-15. The auditorium and gymnasium were operated several times each week. The fuel burned amounted to 1,103 tons of Kentucky nut pea and slack bituminous coal, costing $2.45 per ton. This is a fuel cost for heating and ventilating of .931 cents per thousand cubic feet of space heated per season, or .76 lbs. of coal per cubic foot of space heated per season, which, in view of the considerable amount of coal burned for night use and on account of the swimming pool and shower baths, compares favorably with the records made some years ago by Thos. J. Waters, chief engineer of the Chicago Board of Education. Mr. Waters found that the fuel consumption in elementary schools without gymnasiums, auditoriums and baths, averaged in all blast heating systems, .62 lbs. per cubic foot of space heated per season, while for the so-called split systems it averaged well over one pound of coal per cubic foot of space heated.

## DISCUSSION

The Author: This paper was written in accordance with a letter from the Secretary, suggesting that there would be a number of papers outlining the costs of operation of various heating and ventilating plants, and asking for one on school-house costs. It is, therefore, more elaborate than might be considered necessary, but it was not intended, when it was written, as a paper to occupy the first pages of the Journal.

I intended to describe the system of heating in a large building which has been outlined in my introduction. The general idea was to provide, in a building 365 ft. in length, a system of heating which would enable us to heat the more distant rooms as easily and quickly as those in the center, from a plant located about the center of the building. The interesting things about the plant are that the entire heating of the building is controlled by a pneumatic switch board, and the fact that this building, with boilers of 600 h.p., is capable of being operated by one man, owing to the centralization of the apparatus and the pneumatic control. The entire work of heating, with but few exceptions, is done by the blast system.

In this plant the air is heated at the center of the building to about 68 deg., and delivered through large tunnels to a number of reheating chambers at the bases of the groups of flues. In these chambers the temperature is raised to about 120 deg., and no air is conveyed any appreciable distance horizontally after it is heated. The primary heating coils, or about 2/5 of the total heating surface, are controlled by thermostats. The remaining 3/5 are controlled by the switch board from the engine room, so that the amount of radiation heated may be governed by the demands of the outside temperature. This leads, we have found, to economy in operation. Automatically controlled steam jets are used for humidifying with future provision for an air washer.

The cost of operation as shown in the paper amounts to about 93 cents per thousand cu. ft. per season. The ordinary system of heating with this method costs anywhere from this amount to $2.00. Of course, it is to the advantage of this plant that it is very large and that it is used a great deal for night classes, when from six to ten rooms are utilized. This system particularly adapts itself to that use because by means of it, only the section of the building which is to be used needs to be heated. The auditorium and the gymnasiums are separate units, and they are often used when no other portion of the building is occupied.

J. D. CASSELL: I feel that I owe an apology, as I was appointed a member of a committee to collaborate information on this subject, and failed to prepare anything in particular.

There is, however, something in the paper just read, about which I can speak. We have tried a similar method in our schools with the exception of the centralized control, located in the engine room, and found that it failed, notwithstanding there was no difficulty in raising the temperature of the rooms to 70 deg., as indicated by the thermometers. On every cold Monday morning, we received complaints of cold feet, particularly from the scholars sitting near the exposed walls and window surfaces; by two o'clock the conditions complained of would be overcome. We gave the system up and now use enough direct radiation to take care of the equivalent glass surface and place same adjacent to the outer walls. This answers the purpose better than the plenum system of heating, and has proven much more satisfactory.

I think if the plant described is in a building where night sessions are held, that it is in its favor, and the hand control, if properly operated should prove a source of economy. Nevertheless I firmly believe that eventually the same trouble will arise that I have mentioned.

THOMAS BARWICK: I want to ask Mr. Lewis if he based his calculations on the amount of coal per room. On the cubic foot basis, a great deal of heat is taken up by the halls, corridors and similar spaces, which is not accounted for. Mr. Waters figures that the consumption of coal per room is about 10 lb. In New York, it may be figured from 8 to 12 lb. At the present time I have five or six schools in mind, where we figure about 10 lb. per room, in a building of 8 rooms, and another of 35 rooms, where the auditorium was heated 84 times last winter, that we ran on 7 lb. per room. If Mr. Lewis will enlighten us on the actual coal consumption per room, I think it will come nearer to presenting the subject in a way that we have had it before.

PRESIDENT KIMBALL: My experience has been that it is difficult to figure on the room basis because each architect has a method of his own. It seems to be a matter of opinion, and there is nothing in the nature of a definite standard. The average is about 750 cu. ft. for a high school, and 1,000 cu. ft. for a grade school room, but it differs widely, hence it is hard to check results on such a basis.

RALPH COLLAMORE: I am glad that Mr. Lewis has based his calculations on actual consumption per cubic foot, for I think that all data offered on the room basis is very misleading. Mr. Lewis, I believe, has based his calculations on the inside dimensions of the building including corridors, class rooms, and in fact all space that is heated. It might be well to use the outside dimensions, because this is what the architect does when he figures the cubical contents of a building. I think if this was accepted as a standard it might be helpful in the future.

PRESIDENT KIMBALL: I agree with the last speaker, but even then, it would be difficult to figure approaches, porches, etc.

J. D. CASSELL: Do I understand that the figures were on inside dimensions? I think that they should be outside.

M. WILLIAM EHRLICH: As a suggested standard the term "gross contents" and "net contents" might be used; gross contents would indicate the inside dimensions and the net contents would give the volume of heated space. In this way information on each can be separated, and then one could easily recognize which unit is being referred to.

D. M. QUAY: When we consider cooling surface, glass surface and air leakage, I think it would be well to take the outside measurements. But we make a mistake if we do not consider these factors, and only take inside dimensions. It is misleading to take only outside dimensions; we should take both inside and outside. The outside measurements differ materially from the inside cubical contents, even when figured with well constructed walls, and so it seems misleading to take simply outside measurements without qualifications.

J. D. CASSELL: If we take the inside measurements, and the glass equivalent, would we not obtain the result Mr. Quay asks for? It seems to me we could then agree on a glass equivalent.

THOMAS BARWICK: I base my calculations on a standard room on 10,000 cu. ft. of space; that is the standard size I have usually been figuring.

WILLIAM KENT: I should like to ask Mr. Lewis if there is provision made for recirculating air during the periods of non-occupancy.

THE AUTHOR: The building has a fireproof attic with two very large chimneys leading out of it, which are used instead of ventilators. There is a provision made so that dampness may

be closed out in the above outlets, and so that the air may be recirculated, all under pneumatic control from the switchboard.

If you consider an eight-room school, in which the all blast system is used, there are usually no horizontal ducts of any great length from the blast chambers to the flues. The plenum chamber takes care of all of the eight rooms, and you will usually find that the northwest rooms will be the slowest to heat in the morning. Long after the southwest rooms are warm, these rooms will be too cold. Now, as soon as our first rooms are heated to the desired temperature, all of the heating surface which has been available for these rooms is available for heating up the northwest rooms. This process continues until the entire heating surface is applied to the slowest room to be heated.

The peculiar feature of the design is that the heating surface is proportioned for each class room, but as soon as the rooms that heat quickest shut off, and are getting tempered air, all the heating surface is available for the remaining rooms until finally the entire cumulative effect is available for the last room. In this plant, we can heat the building up to a comfortable temperature, without trouble, and we have had no complaints at all from cold feet.

J. D. CASSELL: I feel that we went even farther than that, Mr. Lewis, for we even put under the floor of each room a reheating nest of radiators. In the northwest room we put a double nest, and in the southwest a single nest. These were operated automatically by a thermostat in the room. If a room got up to 70 deg., it was cut off automatically and the surplus (cost) steam that was thus cut off was available for the radiation in other rooms. Notwithstanding that, on a Monday morning, when the heat had been cut off from Friday afternoon, so that the walls would be cold for the first five or six hours, the teachers made the complaint that while the rooms were plenty warm enough and their thermometers showed 70 deg., still the air was cold around the feet of the pupils, and so we had to give up the system.

THE AUTHOR: That is just the point that I am trying to bring out, between your system and the one I describe; that is your eastern system, while I am trying to show how western practice differs. Your practice is to put into each room so much radiation, and each individual radiator is controlled by a thermostat, placed in the room. When the room gets to the proper

temperature, the thermostat shuts off the heat, and immediately that radiation ceases to pay interest on its investment. It ceases to condense steam to assist in bringing the rest of the building up to temperature. Its work is over when that particular room is heated. That is, we think, a weak point.

In the plant that I describe, the entire amount of radiation, sometimes 15,000 ft., is supplying heat to that last cold room. That is the crux of the situation. I wish to pay my respects while I have the opportunity, to direct radiation as used in the ordinary school room, by saying that in my opinion it is the invention of the evil one, that was brought into use not by engineers but by plumbers. The radiator placed against the outside wall under the windows in the ordinary way is supposed to overcome to some extent the inward leakage of air, the Niagara of cold air that is due to window leakage and cold walls. But the chief result is that the child that sits near it is overheated, and uncomfortable. The radiator does not serve its purpose of heating the incoming air, directly, although it may heat up a portion of the wall surface, or chairs, or something that will heat by radiant heat and then being heated, will warm the air by convection. But the chief accomplishment is that you send about one-half of your radiant heat out of doors when you use direct radiation close against an outside wall.

The first time that I had that brought to my attention was when I was doing some work in Michigan, and there they sometimes get 50 deg. below zero. There was a store to be remodeled, and I was the engineer to remodel the heating equipment. I added about 50 per cent. more radiation to the original job and insisted that it be put in. The owner would not let it go in. I knew that it would not be satisfactory, and said so. It was not put in the way I advised, and it did provide heat enough. But the radiators were not put against the walls; they were set out in the aisles.

J. A. DONNELLY: I do not know that I quite understand "western" practice yet. If you have a building with cold rooms on the northwest and warmer rooms on the southeast, if you intend to have them heat equally, you would naturally provide more heating surface in the northwest room and less for the southeast room.

If the heating is done entirely by the entering air and the rooms are for the same number of pupils, the air should be at a higher temperature for the colder room. This is the case in

the "eastern" practice, but not with the "western." The latter, therefore, intentionally creates the condition which heats the colder room slowly and afterwards claims superiority by remedying the defect.

In New England we used to put an equal amount of air at a uniform temperature in each room and then place varying amounts of direct radiation directly under the warm inlets. The radiators were placed in that location so that they would not interfere with the uniform distribution of the entering air.

THE AUTHOR: The reason for this is that modern research, as particularly the experience of the New York Commission on Ventilation, and that of the Chicago Commission, tells us that currents are extremely desirable.

I cite the tests by various authorities that the more rapid the circulation of air over the radiation the more efficient the radiation. Therefore, why not place the radiation where not only its tendency to create currents, but also the tendency of the windows to do so, will assist each other?

No. 400

# OPERATION OF WAREHOUSE HEATING PLANT OF MERCK & CO., RAHWAY, N. J.

By J. F. Cyphers, Rahway, N. J.

Member

THE buildings heated by the present heating plant are the main warehouse, the liquid building, the workshop building and four small sheds, located as shown on the plan (Fig. 1).

The main warehouse is of slow burning mill construction, 120 ft. wide by 650 ft. long, consisting of twenty-one saw-tooth sections, divided into rooms, some 60 by 120 ft. and others 125 by 120 ft. The building has concrete floors, on the ground, is one story high, 12½ ft. being height from the floors to bottom of the trusses, and 11 ft. from bottom of the trusses to peak of the saw tooth. The saw tooth windows face the north. In each saw tooth is about 700 sq. ft. of wire glass surface. The rest of the roof is composed of 3 in. plank, with 2 in. air space, then ⅞ in. boards and 5-ply Barret roofing paper. The 16 in. brick wall on each end of each saw tooth section contains either two windows 4 by 8 ft. or one door 6 by 10 ft., and one window 4 by 8 ft. Sixteen of these sections contain only 1¼ in. pipe coils, suspended under the saw tooth skylight, some having 750 sq. ft. of surface and others 900 sq. ft. The remaining five sections, built in 1914, contain 850 sq. ft. of radiation each, 500 sq. ft. in the form of 1¼ in. pipe coils in the skylight, 200 sq. ft. along the west wall, and 150 sq. ft. along the east wall. The total radiation in this building is 17,850 sq. ft. at present.

This building is occupied by several hundred people, mostly girls, who do not dress warmly, and as a result, are rather sensitive to temperature changes. They require as a rule that the temperature be kept within 2 deg. of 70 deg. during working hours. No special apparatus is provided for ventilation in the

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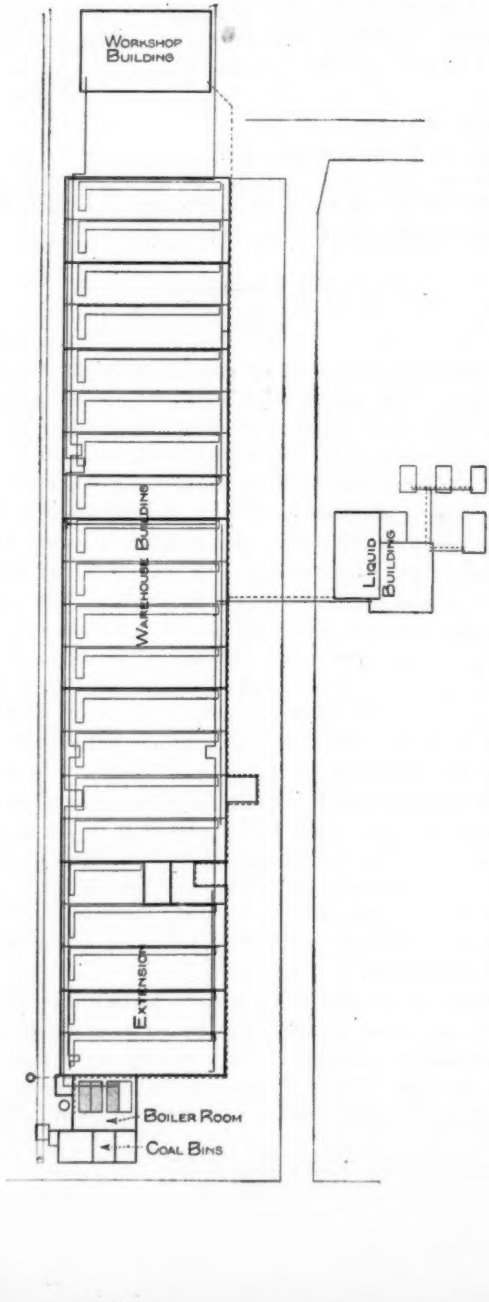


FIG. 1. PLAN OF WAREHOUSE AND OTHER BUILDINGS HEATED FROM PRESENT PLANT.

various rooms of this building because the cubical contents are so large compared with the number of occupants that no need has been felt for mechanical ventilation.

Previous to 1914 the main warehouse consisted of sixteen saw tooth sections, provided with the same radiators in use to-day. The steam for these radiators was supplied by a 5 in. main from the factory boiler room, 600 ft. away, carrying 100 lb. pressure, through a reducing valve, which maintained a pressure in the heating system varying from 0 to 15 lbs. The reducing valve was situated at one end of the building, which was then 500 ft. long, and a vacuum pump was situated near the reducing valve, returning water to the factory boiler room.

The operation of this system was left to the janitor of the building, who looked after it whenever there was a complaint in regard to the heat, or when his other duties allowed him. Steam was turned on from the factory boiler room at a specified hour every day of the heating season, regardless of weather conditions, and was turned off if the building became unbearable after the doors and windows had been opened.

The liquid building is of fire-proof construction throughout, of irregular shape, roughly, 60 by 60 ft., one story in height, with a cellar 20 by 60 ft. under part of it. It contains a total of about 1,200 sq. ft. of wall radiation. The opening of the doors of this building for moving materials in and out, as well as some ventilators in the roof, keep the place sufficiently well ventilated. The building is occupied by men and boys. The nature of the contents requires a temperature not lower than 50 deg. Fahr. day or night the year round.

This building, which was erected in 1910, was provided with an individual heating system. On account of its floor level, and its distance (about 100 ft.) from the main warehouse, it was thought impossible to connect it to the main heating system. A cast iron boiler was installed, and connected to a so-called vapor system of heating which was not suitable and hence failed to work. There were certain radiators in this building which it was found impossible to heat from the cast iron boiler, regardless of the effort made to do so. As a result, material liable to be damaged by low temperatures, had to be removed from the building in winter and it was impossible to work there except in certain rooms. The watchman whose duty it was to look after this boiler at night, one night in December, 1913, neglected it, and the next morning we discovered that the water in the boiler had frozen and burst the boiler, so that it was beyond repair

Within two days a high pressure steam line had been run to the building, a reducing valve installed, the piping changed, and for the first time all the radiators heated properly. In the summer of 1914, the heating system in this building was completely remodeled and connected to the main warehouse heating system.

The workshop building, erected in 1910 is of slow burning mill construction, 60 ft. wide by 90 ft. long, and contains 1,000 sq. ft. of wall radiation. The temperature of this building is not of importance, and is generally carried between fifty and sixty degrees in the day-time. There is no heat on at night. It was formerly heated by exhaust steam in mild weather and steam at 100 lbs. pressure in cold weather.

The four sheds have about 50 to 100 square feet of radiation each (a total of 600 square feet), and are only heated when in use. These were erected in 1914.

All of the above buildings are situated in a flat country, with their floor level about 25 ft. above mean tide (Sandy Hook), are exposed on every side, and are difficult to heat in cold, windy weather. They are equipped throughout with automatic sprinklers, wet pipe system.

The boiler room is situated at the southwest end of the property and forms an addition to the main warehouse, but its floor level is 6 ft. lower. The boiler plant consists of three 150 H.P. horizontal return tubular boilers forming one and one-half batteries. Room has been left in the boiler house for the fourth boiler, and the chimney and flue pipe are of ample capacity to take care of it.

The heating system vacuum pump is placed on the floor of the boiler room, and transfers the return water directly from the return main to an overhead tank provided with overflow. The boiler feed pumps and receiver are fed from the overhead tank. The only valve which is ever manipulated to regulate the boiler feed when the plant is in operation, is the steam throttle valve on the vacuum pump. On the wall is a gauge board containing a recording pressure gauge showing boiler pressure, a recording vacuum gauge showing the vacuum in the return system near the pump, an indicating compound gauge showing pressure at the end of one of the radiator feed mains, and an indicating vacuum gauge connected at the same point as the recording vacuum gauge.

Running the length of the boiler room and as additions to it are the concrete coal bins which hold 400 tons of coal. These

bins are filled by means of a coal conveyor from cars standing on the siding alongside the boiler room.

From the boiler room a 6 in. high pressure main runs 400 ft. to the center of the west side of the main warehouse building and to the same point a 5 in. high pressure main is run from the factory boiler room 900 ft. away. This point is known as the distributing point. Here is situated a reducing valve and also the beginning of the low pressure feed mains to all radiators of the system. A 7 in. main runs north, and another south to each end of the warehouse building, feeding the overhead radiators. The one to the north also feeds the workshop building. Across the warehouse an 8 in. main is run with a small main to the south for the purpose of feeding wall radiators on the east side of the building, and from this side is run an overhead line to the liquid building. The 8 in. line is to feed the radiators in a large extension planned for the northeast end of the warehouse, in addition to its present use. The sheds are fed from the line to the liquid building.

The return main is a 4 in. pipe laid along the east side of the building, outdoors, below floor level, from the point of the beginning of the proposed warehouse addition to the boiler room, and has sufficient capacity to take care of the returns from this addition. It was impracticable to run a return main on the west side of the building either outside or inside.

One unique feature in the return system is the gathering of the returns from the liquid building and sheds, where the floor level is over 4 ft. below the floor level of the warehouse. A 1½ in. return main runs from the liquid building across a road, through an underground insulating system to a drip pocket and rises 5½ ft. into the top of the 4 in. return main. This has worked perfectly, and last winter was the first in which this building was satisfactorily heated.

At the boiler room the return main divides, one branch going to the vacuum pump, and one branch to the boiler blow-off pit. Each branch is controlled by a valve. By this method it is possible to run the plant on the gravity system if it should become necessary, and it is often operated in this way on the mild days of fall and spring. When operating this way the return water from the liquid building is run to the sewer.

The boiler safety valves are set at 125 lbs. pressure. In starting up the plant, the radiator feed main pressure never exceeds three pounds per square inch even in the coldest weather, and generally either no pressure or ½ in. vacuum is carried. The

vacuum carried on the return system varies from 10 to 12 in., and is fairly constant. Jet water is never used. The boilers are blown down about twice a week, and then make-up water is added to the system through the overhead tank.

The temperature of the warehouse is never allowed to fall below 45 deg Fahr., and during working hours it is kept between 68 and 72 deg. In order to maintain these temperatures in the coldest weather it is necessary to operate the heating plant twenty-four hours a day. However, the number of hours a day that the heating system is run is left to the discretion of the engineer-in-charge, who has the plant started up sometimes at 5 A.M., 4 A.M., 3 A.M., or 2 A.M., according to weather conditions, so that the temperature will be seventy degrees when the employees arrive at 8 A.M. It is by this scheme of watching the weather changes from day to day and making the hours of operation of our heating plant correspond thereto that we obtain the most economical operation and at the same time the most satisfactory results.

The coal is weighed before being fired, and a weekly log sheet is kept of the operation of the plant. As an additional check on the firemen we have the charts from the recording gauges, showing boiler pressure and vacuum in the return system.

Recording thermometers and indicating thermometers are distributed throughout all the buildings. As a rule the radiators are turned on or off by the occupants of the room, but a check on them is kept by frequent inspections made by the engineer-in-charge, as the tendency is when it becomes too warm to open a window or door rather than shut off a radiator.

Although we have tried this plan of operation but one year, the results compared with previous years both as regards economy and maintaining temperature have been so gratifying that we are proceeding with the same method this year.

The cost of supervision, labor and supplies, such as cylinder oil, waste, etc., last year totaled $640.62. The coal burned was 325 tons, at $3.50 per ton in the bins, which makes the cost of coal $1,137.50. This makes the total operating cost $1,778.12 for a season, which extended from November 1st to May 15th, or .086 cents per square foot of radiation. To this should be added heating plant repairs, interest on investment, and depreciation of plant to get the real total yearly cost of heating. This figure was not available at the writing of this paper, but is estimated at $2,400, making the total yearly cost of heating, roughly, $4,200. The total radiation is 20,650 square feet, making the

total cost of heating per square foot of radiation 20.3 cents per year. $\frac{325 \text{ tons}}{20{,}650 \text{ sq. ft.}}$ = 31.4 lbs. coal per sq. ft. rad. per season.

The exact cost of operation of the heating system was not kept previous to 1914, but a very close approximation from records at hand has been made, giving the old system the benefit of every doubt. The cost for coal, firemen's wages, boiler repairs, etc., average for the five years previous to 1914, $2,200 per year, for the sixteen sections of the warehouse only. Heating system repairs, which are, however, small, are not included in the above figure. The liquid building system used hard coal. No figures are available as to the cost of operation of this system, but it must have been an item, when the cost of hard coal, ash removal, and attention are considered. The workshop building was heated generally by exhaust steam so that no account need be taken of the cost of heating this building.

To compare the cost of operation of the old with the new system the following estimate was made:

| | |
|---|---|
| Heating 21 sections of main warehouse on same pro rata as 16 sections | $2,887.50 |
| Heating fireproof building with hard coal | 278.00 |
| Cost of coal and labor, old system | $3,165.50 |
| Cost of coal and labor, new system | $1,778.12 |

Assuming depreciation and repairs to be $1,800, which is about right, the total cost of heating for the season would be, $2,200 plus $1,800, or $4,000. The total radiation was 12,600 square feet, which made the total cost of heating per square foot of radiation 31.7 cents per year, with the old system and method of operation.

In consideration of the extreme length of the building, the small difference in level between boiler room floor and warehouse floor, the large glass area in each saw tooth, the extreme exposure from every side, the temperature control required not only during working hours but at all times on account of the nature of the contents, the fact that exhaust steam is not available for heating but that live steam needs to be used, we believe the cost of operation of this heating system to be exceptionally low, and that the cost shows the result of the utmost care in operation.

## DISCUSSION

ARTHUR RITTER: Figuring cubical contents per square foot of radiating surface for the warehouse which covers over 85 per cent. of the system, you get 80 cu. ft., which would indicate an efficient heating system and a good tight building, considering the saw-tooth roof construction and extreme exposure. From this we can also assume that the inward leakage of fresh air is very small. Some three hundred people are engaged in this warehouse, mostly girls, so that some system of mechanical ventilation would be worth considering. A properly designed fresh air supply ventilating system would require from 25 to 30 boiler h.p. in addition to the present heating system in zero weather, which includes steam for the tempering coils and fan engine.

As regards the cost of operation, this also appears to be quite economical. From a table in Mr. Martin's paper we find that the average cost for a building of the same cubical contents would be $2,300 per year, including fuel, labor, ash removal, make-up water, supplies and repairs.

I would like to ask Mr. Cyphers if the steam supply to the liquid building and work-shop are above or underground, and how insulated.

E. L. HOGAN: I beg to call your attention to several points in connection with the paper read by Mr. J. F. Cyphers.

It appears that on account of it being necessary to use live steam for the heating of this building and those adjacent, and the further fact that the factory power-house, 900 ft. away, probably has a full load, a separate boiler plant was installed adjoining the warehouse. This simply provided another means for supplying steam to the buildings to be heated.

The fact that the liquid building had a poorly designed system with an inadequate boiler, of course gave an opportunity for a saving in connection with this plant. It goes to show that it is not always necessary to install independent boilers in a building requiring a little different treatment than the rest of a plant, even though this building be separated some distance from the main building. It proves that with proper design and installation, results can be accomplished.

The warehouse building is not a hard building to heat. The roof is low and of very good construction. The saw-teeth of course have considerable exposure in the skylights but the end walls and roofs of these saw-teeth are well constructed. It is

not necessary to maintain a very great difference in temperature between the floor and ceiling of this building and while the exposure is large in proportion to the volume, yet it is smaller in proportion to the floor area and space utilized than a building with a high roof.

It is apparent from an analysis, that the great saving in connection with this heating plant was made by watching the operation. In this particular case steam was made especially for heating, and the less used the less work the firemen would have in shoveling coal and ashes. The boiler room being adjacent to the warehouse gave an opportunity of frequent inspections of the system and adjustment to meet the heating requirements.

The average requirements of a heating system are about one-half the maximum; consequently, if one-half of the heating surface is utilized, or if the steam pressure and vacuum are so arranged that only one-half of the steam is condensed, it is apparent that a great saving can be made.

I believe that this paper is a good example of what can be accomplished by intelligent operation. If operating engineers would open up their minds a sufficient amount to accept a little information from experts in the various lines of business, they no doubt would receive valuable pointers on the operation of their own plant.

There are two things necessary in order to have the satisfied customer: *First,* a heating system must be designed and installed properly. *Second,* it must be operated properly and I believe that a good operator is more important than a good system, but a good system is necessary in order to keep a good operator.

As to the cost of operation per square foot of radiation, I am not in a position to judge, for the reason that it would seem as though the depreciation in connection with the old system was higher than it should be. If you depreciate the old plant $1,800, most of which I presume applies to the boiler plant supplying the steam, what is done with this amount of depreciation or what carries it, after the new plant is installed and which is depreciated $2,400 yearly? Possibly a little information on this point might help matters a little.

J. A. DONNELLY: In regard to Mr. Ritter's suggestion that mechanical ventilation might help, it was figured when the system was installed that the allowance of one-half an air change per hour would allow a standard of 30 cu. ft. per person

per minute, for all the persons occupying the room. In view of the size of the room it was decided that this would be satisfactory, and that the natural leakage would afford sufficient ventilation. The number of doors is unusual and they are fairly leaky, and this affords sufficient ventilation, especially in cold weather. There is really no need for mechanical ventilation.

F. K. DAVIS: I noticed one thing in the paper that brought to mind some of our discussion of the afternoon, on the cost of labor. It was stated that this usually equals the cost of coal. I notice that the labor charge on this job amounts to something less than $100 per month, slightly more than one-half the cost of the coal. That is one point that I should like cleared up. Was all the time of an engineer devoted to this, or was part of his time charged to some other portion of the operation costs? I should like to know how the labor cost was arrived at.

M. WILLIAM EHRLICH: The cost of operation as given by the author is interesting. The figure of 20.3 cents per square foot of radiation per year for a warehouse does not seem high. I have some similar figures which show that the average cost in loft buildings under New York conditions is 18 cents and in office buildings only 15 cents. These figures are given as information for comparison.

RALPH COLLAMORE: I should like to talk a little on the topic of ventilation due to air change from natural leakage. If we understand the subject of ventilation correctly, this type of ventilation would be purely local, whereas the technical system would distribute the air thoroughly and evenly.

In my opinion, we are hardly prepared to acknowledge that a mechanical system of ventilation would not be much more efficient than a system that depended upon air leakage.

THE AUTHOR: There is an overhead feed main running from the warehouse to the liquid building and an underground return pipe, insulated by asbestos and laid in vitrified tile, back to the main return line.

As to labor charges, there is sufficient other work about the plant to keep the fireman busy, and we charge only the time that he actually spends on this work. For instance, if he is at this building from 5:00 A. M. to 11:00 A. M., only that time is charged, the rest being charged to the factory boiler room or the shop.

There is a fixed charge for supervision, which is charged at so much per month for the entire heating plant.

The system used is a two-pipe vacuum system, with differential valves.

Regarding ventilation, most of the people employed in this building are moving around all the time. It is not as though they were working at a table or bench all day. But in one room we are now considering the installation of a system of ventilation, to overcome some difficulties that are experienced there.

No. 401

# HEATING A CHICAGO OFFICE BUILDING

By S. Morgan Bushnell, Chicago, Ill.

Member

IN the following description of the heating of a large office building, an attempt has been made to give a practical illustration of the heating requirements of a modern office building and to show in a general way the relation between theoretical calculations and the actual results under typical operating conditions.

The building under consideration (see Fig. I) is located at the northeast corner of Clark and Adams Streets, Chicago, is 181 feet by 190 feet in area with a height of 260 feet, and above the fourth floor has a court 60 feet by 120 feet.

The building was formerly occupied by the Continental & Commercial National Bank, but on the completion of their new structure at Adams and La Salle Streets, the bank moved out and the building has since been occupied by the Commonwealth Edison Company, the local company which supplies electricity throughout the city.

The building was formerly equipped with plunger hydraulic elevators which were operated in connection with a steam plant which also provided steam for heating and for driving the electric generators that furnished light and power in the building. About two years ago the dynamos and engines were removed and the plunger hydraulic elevators were replaced by one-to-one traction type electric elevators. The building now purchases electricity from the Commonwealth Edison Company and steam from the Illinois Maintenance Company, according to the regular printed contracts of these companies. This change in the method of operation has resulted in a substantial saving in the annual operating costs of the building.

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Presented at the Annual Meeting of The American Society of Heating and Ventilating Engineers, New York, January, 1916.

The consumption of electricity is high for a building of this size due mainly to the fact that it is the headquarters of the Commonwealth Edison Company which uses light very lavishly both in its offices and in its show-rooms on the first floor. The steam requirements are also high due to the fact that steam is left on all night to accommodate some of the employees of the Edison Company, particularly the load despatcher's office.

In accordance with the policy of a number of large Chicago office buildings, the building management has made a contract on the meter basis with the Illinois Maintenance Company to supply steam from the boiler plant in the basement in accordance with their regular price schedules. An arrangement is also made with the Illinois Maintenance Company to supply labor to take care of the plumbing, radiation and electrical apparatus up through the building, also for the maintenance of the elevator system.

Steam is used simply for heating and hot water service in the building and accordingly the summer requirements are comparatively small. During the past summer season, the weather was especially cool and steam was required for heating the building at times even in the summer months.

The steam is measured by St. John meters, and the following table shows the requirements during the past year beginning with December, 1914:

| Months. | Lbs. of steam | Cost. |
|---|---|---|
| December, 1914 | 9,358,000 | $3,481.38 |
| January, 1915 | 10,014,000 | 3,717.54 |
| February, 1915 | 7,815,000 | 2,925.90 |
| March, 1915 | 8,390,000 | 3,132.62 |
| April, 1915 | 3,642,000 | 1,423.62 |
| May, 1915 | 3,356,000 | 1,320.66 |
| June, 1915 | 897,000 | 430.79 |
| July, 1915 | 441,000 | 238.95 |
| August, 1915 | 482,000 | 257.40 |
| September, 1915 | 794,000 | 389.07 |
| October, 1915 | 2,754,000 | 1,103.94 |
| November, 1915 | 5,121,000 | 1,956.06 |
| Totals | 53,064,000 | $20,377.93 |

From the above it may be seen that the cost of steam service in the building amounts to about $20,400.00 per year, at an aver-

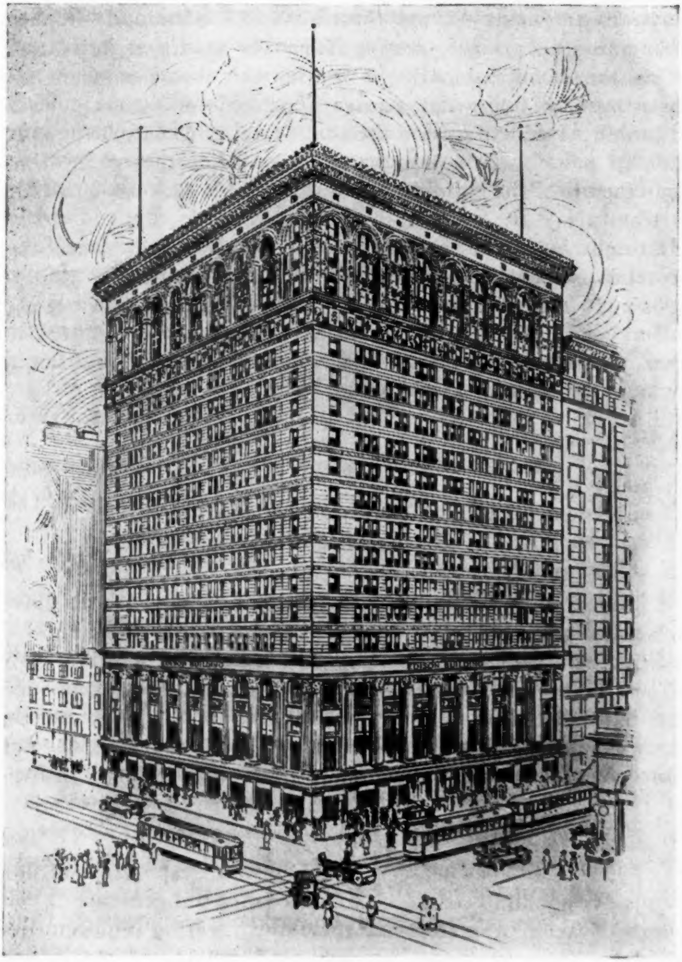


FIG. 1. THE COMMONWEALTH-EDISON COMPANY BUILDING, CHICAGO, ILL.

age price of a little over 38 cents per thousand pounds. This price is very low due to the fact that the heating company does not have any investment in boilers or steam pipe lines, the steam generating plant being furnished by the building, while the heating company simply furnishes the labor and supplies to operate the plant. Judging from the steam that is used during the summer months, it is assumed that the steam requirements for hot water service approximate 500,000 pounds per month. Deducting from the above total of 53,064,000 pounds 6,000,000 pounds for hot water service, makes the net heating requirements of the building in round numbers 47,000,000 pounds of steam per year.

It might be interesting to make a comparison between the theoretical steam requirements and the actual results. The building is a modern steel and terra cotta building, having an outside wall exposure of 149,192 square feet, glass surface of 85,558 square feet and a roof surface of 27,190 square feet. The formula used by the heating company is:

$$T = \frac{S \times .2}{E}$$

in which

T = Number of tons of coal used per year.
S = The equivalent glass surface in square feet.
E = The factor of evaporation.

In order to find the equivalent exposure in square feet of glass surface, to the total glass area add one-tenth of the net wall area, including the roof, allowing 10% additional for the north and west exposures. It has been found as a matter of experience that in this building an average evaporation of 5½ pounds of steam per pound of coal is obtained. The equivalent glass exposure equals 107,031 square feet. Substituting these values in the heating formula gives $\frac{107{,}031 \times .2}{5\frac{1}{2}}$ or 3,892 tons of coal per year. Taking our evaporation of 5½ pounds per pound of coal, each ton of coal would generate 11,000 pounds of steam; therefore the theoretical heating requirements would be 3,892 × 11,000, or 43,812,000 pounds of steam per heating season. This figure assumes that the building is equipped simply with direct radiation. In this particular building, there is an equivalent heating surface in the indirect system for the basement and lower floors of 4,000 square feet, assuming that the indirect radiation will require double the amount of

steam per square foot that the direct radiation requires. Taking one-half of 4,000 square feet times 783 pounds of steam per square foot per season, gives an additional 1,566,000 pounds. Adding this to the theoretical requirements in direct radiation, there is a total of 45,378,000 pounds per year. As compared with the actual results or 47,000,000 pounds during the past season, the consumption is a little over 3½% above the theoretical requirements. This may be explained partly by the fact that the temperature during June and September, 1915, was below the average, requiring steam for heating at certain times, and also by the conditions above stated, viz.: the unusual steam requirements at night.

The installed radiation in the building is about an equivalent of 60,000 square feet of direct radiation. Dividing this into 47,000,000 pounds of steam, we have a consumption of 783 pounds of steam per season per square foot of radiation. This amount is a little higher than has been found customary in similar buildings in Chicago. This may be explained by the fact that the radiation installed is slightly under the customary required amount, viz.: 107,000 the equivalent glass surface $\times \frac{6}{10}$ equals 64,200 square feet.

The accompanying diagram (see Fig. 2) shows the general arrangement of the heating equipment in the building. It will be noted that the design is a one-pipe over-head or down-feed system and it is operated with the Paul vacuum system and Johnson thermostatic type of heat regulation. The heating throughout the building is done by means of live steam, the steam being furnished from the boilers at a pressure of 90 pounds and expanded through a 12-inch reducing valve into a tank at a pressure slightly above atmosphere depending upon the temperature. As shown in the illustration, the steam for the upper floors is carried through an 18-inch riser to the roof where distributing lines connect with branch risers leading to the basement return headers. The heating of the first floor is supplied by a separate pipe feeding from the expansion tank. There is also a separate supply leading to the heating coils of the indirect heating system. The Paul air valve lines are carried from the different radiators alongside the risers to the basement where they enter a manifold connected with the suction of the vacuum pumps. The bottoms of the various risers are connected to basement return headers which carry the return water

of condensation back to the heaters, whence it is pumped back to the boilers.

The St. John meters are installed where the main steam line leaves the boiler header and there are two 6-inch meters in multiple for the maximum load. Thus far one meter has been found sufficient, even in cold weather, and the valve to the other meter is closed. The system operates under average conditions with 18 inches of vacuum.

There are about 78 secondary steam risers, each riser having a diameter of 3 inches at the upper floors and 2 inches at the basement. The thermostats are placed at suitable points in the different rooms, it being the endeavor to locate them at points in the room where the average conditions of heat prevail. The radiators are all located at the windows with a view to minimizing changes in radiation when partitions are removed.

The air pressure for the Johnson system is supplied by two 3-horsepower motors which consume about 27 kilowatt hours per day. The air pressure used is about 15 pounds per square inch.

Inasmuch as some buildings provide the steam heating from a plant which also furnishes electric light and power, the itemized costs of central station electrical service in connection with the miscellaneous supplies required in the building are also given in order to show the relation between the different items and to make easier a comparison with other buildings.

The figures on the electrical consumption cover the same period as those given above for the steam consumption and are as follows:

| | K.W. Hours |
|---|---|
| December, 1914 | 84,640 |
| January, 1915 | 84,890 |
| February, 1915 | 109,480 |
| March, 1915 | 127,000 |
| April, 1915 | 129,510 |
| May, 1915 | 126,200 |
| June, 1915 | 126,310 |
| July, 1915 | 126,860 |
| August, 1915 | 138,850 |
| September, 1915 | 170,055 |
| October, 1915 | 157,205 |
| November, 1915 | 218,926 |
| Total | 1,599,946 |

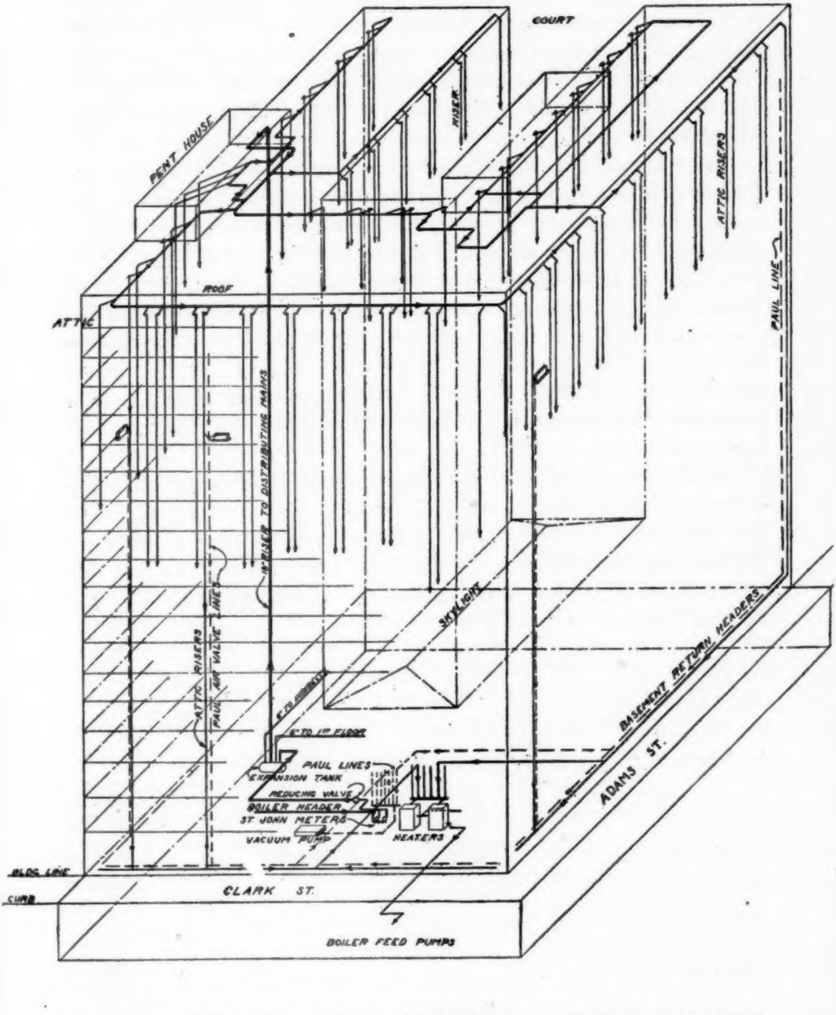


FIG. 2. DIAGRAM OF BUILDING SHOWING ARRANGEMENT OF HEATING EQUIPMENT.

The total consumption for the year for elevators was 390,610 K.W. hours; for miscellaneous power 208,250 K.W. hours; for corridors and public lighting 128,190 K.W. hours; for tenants including the electricity used by the Edison Company 872,896 K.W. hours. The rate earned by the building under the lighting company's wholesale schedules is less than 2c per K.W. hour, making the total cost of electricity for 1,600,000 K.W. hours about $32,000.00.

Inasmuch as the largest tenant is the Edison Company, the building does not derive any profit from retailing electricity for a large portion of the space. If all the electricity used by tenants were sold by the building, as is the case in a number of other buildings, at an average of 5 or 6 cents per K.W. hour, the income from the tenants would more than pay for the entire cost of the electricity for the building. The comparatively low consumption of electricity during the first months of the year was due to the fact that several floors of the building were being remodeled for the use of the various departments of the Edison Company which moved in during the year.

In addition to the cost for steam and electricity, the building pays the Illinois Maintenance Company approximately $4,000.00 per year for the care of fans, radiation, plumbing and elevators throughout the building. It also pays $3,300.00 per year for two electricians employed in the building. The building has the following expenses for supplies:

| | |
|---|---|
| Electrical supplies | $ 474.00 |
| Elevator supplies | 1,038.00 |
| Heating supplies | 493.00 |

Summarizing the above, we have as follows:

| | |
|---|---|
| Electricity | $32,000.00 |
| Steam | 20,377.93 |
| Additional labor furnished by heating company | 4,000.00 |
| Electricians | 3,300.00 |
| Electrical supplies | 474.00 |
| Elevator supplies | 1,038.00 |
| Heating supplies | 493.00 |
| Total | $61,682.93 |

In round numbers, therefore, the cost of heating and furnishing the electrical requirements of this building which as seen from the above are unusually heavy, amounts to about $62,000.00 per

year. Three years ago, the cost of operating the building from a private plant with hydraulic elevators, including fixed charges on the investment for dynamos and engines, was about $75,000.00 and the electrical requirements amounted to about 1,300,000 K.W. hours per year, low efficiency lamps being used at that time. Comparing the cost of steam therefore with the total cost of operating a complete plant, we see that the ratio of the heating cost to the total is about the same as one to three and one-half.

In a paper read before the association last September by Mr. James A. Donnelly, an interesting table was given for the transmission of heat at various temperatures from cast iron radiators. Where the steam temperature is 210 degrees, the transmission is given at 250 B.t.u. per hour per square foot of radiation. The ordinary heating season in Chicago is 243 days. The average period during which steam is on the radiators of an office building will run about 12 hours per day. If in this particular building we assume a little higher average, perhaps 13 hours per day, there will be 3,159 hours during the heating season; 250 B.t.u. per square foot per hour, times 3,159 hours gives 790,000 B.t.u. per square foot of radiation. Assuming about 1,000 B.t.u. for each pound of steam gives 790 pounds of steam per square foot of radiation. Multiplying this by the total of 60,000 square feet, gives 47,400,000 pounds as the amount of steam which would be used during the season. This is a little higher than the actual consumption of steam in the radiators. The maximum steam consumption during the winter in any hour as shown by the meter charts was 17,800 pounds per hour. This at 30 pounds of steam per boiler horse power would be the equivalent of approximately 600 horse power. A comparison with the total square feet of radiation gives a ratio of one horse power in boiler capacity used to each 100 square feet of radiation.

The question frequently arises as to whether it is possible by making a test on the heating requirements of a building during two or three days, to approximate the heating requirements during the entire heating season. About the middle of November 1915, the daily mean temperature for about a week averaged between 38 and 40 degrees. If the heating season in Chicago is taken as beginning October 1st and ending May 31st, or a period of 243 days, the average temperature during that time is 39 degrees. It would therefore be interesting to find out whether the consumption of steam during these days (which happened to have average temperatures for the season) corresponds with the average for the heating season. Deducting the steam consump-

tion during the four months of summer, there is an actual consumption for the heating season of 50,450,000 pounds. During this week in November, while the average temperature was about 39 degrees, the meter showed about the same consumption each day, viz.: 210,000 pounds. Multiplying 210,000 pounds by 243, the number of days in the heating season, gives a total of 51,030,000 pounds. This checks very closely with the actual consumption of 50,450,000 pounds, and would tend to indicate that where the temperature is approximately stationary for several days, a fair idea of the heating requirements for the season can be obtained from a short test. This probably would not prove true if the temperature should vary greatly from day to day as there is a certain lag between the steam requirements of a building and the outside temperature.

In making estimates based on such tests, it of course should always be borne in mind that the steam requirements are not proportional to the variation in outside temperature but to the difference in degrees between the indoor temperature and the outside temperature.

It is very interesting to check the various theoretical formulas which have been proposed, with actual conditions in the heating of buildings. The empirical formula which is used in Chicago for estimating the heating requirements of large buildings not only is based on experience from heating a large number of buildings, but also has been deduced by taking certain values in the general formula for heating, which is based on the amount of heat radiating surface on the outside of a building and the rate at which the air is changed in the building through ventilation and leakage. There is perhaps no line of endeavor in which it is more necessary that theory and experience walk side by side than in the subject of heating and ventilation. In view of the fact that fairly satisfactory and dependable instruments can now be obtained for measuring the quantity of steam and the pressure which is maintained, a large amount of information should be collected as to the heating requirements in various classes of buildings.

In conclusion, the suggestion is offered that it might be advisable to have a committee formulate rules in regard to the keeping of this class of data so that accurate information regarding a great many buildings may be obtained along the lines indicated by the "Questionaire" recently sent out by this society.

## DISCUSSION

W. H. Driscoll: I have a few points which I think I can best present in the form of questions I will ask Mr. Bushnell:

1. I note that the evaporation is given at 5½ lb. per pound of coal. That seems low. What kind of coal was used?

2. There is a statement made in the paper that I do not quite understand. It is stated that there is an equivalent heating surface in the indirect system of 4,000 sq. ft.; assuming that the indirect radiation will require double the amount of steam per sq. ft. that the direct radiation requires, you take 783 and multiply it by 2,000. I cannot quite follow your reasons for this.

3. In the paper, it is stated that the system operates under average conditions with 18 in. of vacuum. This is a one-pipe system with temperature control; I would like to ask in the first place what advantage is gained in operating under a vacuum? Do you have any trouble from condensation being held in the radiators? I ask this because I have personally had a similar experience in New York where a one-pipe job was used, but there the branches were long and we had a great deal of trouble in getting rid of condensation. We finally had to change the system to a two-pipe, using traps on the return end of each radiator, and used the air line for the return lines. Mr. Bushnell makes no mention of such trouble and I thought perhaps he had some condition that had not occurred to me that enables him to overcome anything of this nature.

4. In mentioning Mr. Donnelly's paper, there is a statement of the amount of steam used. It seems to me that, considering the calculations given, even though we allow an average heating season of 243 days and an average operation of 13 hours per day, the steam consumption is extraordinarily high, and particularly in view of the fact that temperature control is in operation on the job. It seems to me that the steam consumption is larger than it should be, and that the statement should be revised to more nearly meet the actual result which is being obtained.

A. M. Feldman: How many cubic feet are there in the building and what kind of pumps are used?

W. S. Timmis: Will Mr. Bushnell explain how the formula is divided. It is stated that, $T = \frac{S \times 0.2}{E}$ but it is not exactly clear?

D. M. QUAY: I was going to ask about the 18 in. of vacuum, but Mr. Driscoll has already mentioned that, so it will probably be answered. It is conceded, I think, that 2 in. is sufficient vacuum at a radiator, and the amount of vacuum at the pump is governed by the friction loss, etc., from the pump to the radiator. There is something wrong with the system if it is necessary to carry 18 in. at the pump that 2 in. may be obtained at the radiators. I should like to know why this high degree of vacuum is required.

J. J. BLACKMORE: Mr. Driscoll asked about Mr. Donnelly's table of transmission of heat, which Mr. Bushnell mentions in his paper. I do not think Mr. Bushnell does himself justice in using this calculation in his paper, for Mr. Donnelly bases these figures on 70 deg. inside and 0 deg. outside.

The average temperature in Chicago is higher than zero, and therefore if the calculations were made in accordance with Mr. Donnelly's figures, the consumption of steam would have been less. I also think that 13 hours for the radiators to be operated is high. If the time was cut down and the transmission figure based on the average temperature for the winter, it would only be about two-thirds of the 250 B.t.u. given per hour in Mr. Donnelly's table.

F. K. DAVIS: I should like to ask Mr. Bushnell whether in figuring the radiating surface he took into consideration risers and supply pipes, and figured them on a basis of 250 B.t.u. Are they figured in the amount of steam used?

THE AUTHOR: I think I have all the questions now and will try to answer them in their order:

1. The pounds of evaporation given as 5½ does sound low but it should be remembered that this is the average for the year and furthermore that it is the actual pounds of steam delivered through the meter, as compared with the pounds of coal actually fired. This of course is different from the technical factor of evaporation from and at 212 degrees. During the past month the pounds of steam per pound of coal ran as high as 6.76 but last summer we had to contend with an evaporation of only 3 lb. of steam per pound of coal. We were operating with large sized boilers. Our smallest boiler was 350 h.p., while the maximum load was less than 100 horsepower which naturally brought down the evaporation. Another thing to be borne in mind is that the company makes a special effort to deliver constant service. There is always a question as to

whether to get the highest possible efficiency or to provide constant service. A great deal of the time we have a boiler in bank ready to be put in service, because we do not wish to take any chances on even a temporary shortage of steam.

2. In regard to the radiation, would say that there are two thousand square feet of indirect radiation which we assumed was equivalent to four thousand square feet of direct radiation. Accordingly the actual equivalent of direct radiation would be two thousand square feet more than the theoretically required direct radiation. Inasmuch as the formula is based on heating with ordinary direct radiation and inasmuch as the actual condition given us for heating requirements is the equivalent of two thousand square feet of direct radiation additional, in figuring out the steam consumption from the formula we would have to add 2,000 times 783 lb. of steam or 1,566,000 lb.

3. Referring to the question, regarding the use of the vacuum system would say that I feel there are other men here more competent to discuss the relative merits of vacuum systems. This system was installed by a well known firm of architects D. H. Burnham & Co., who probably were well satisfied that they had good reasons for installing it. As far as actual operation is concerned it works very satisfactorily. The day before I left Chicago, we had zero weather with only one heat complaint in the building. The amount of vacuum is of course more than is ordinarily necessary, but this same pump is used in providing vacuum for several buildings in the block which are some distance away and the natural result is a higher vacuum than is necessary on our own building. This matter is easily adjusted, however, but cutting down the steam pressure to atmosphere or a little below. As to having any trouble with getting rid of the condensation would say there has been absolutely no trouble in this regard. It should be noted that this system is a "Mills" system in which the steam is first carried to the top of the building so that the returns travel downward through the risers in the same direction as the steam.

4. Regarding the comparison with Mr. Donnelly's paper would say that these figures are perhaps open to question. At the same time, they correspond fairly well with two other large buildings in which the average consumption worked out as 12 hours per day. As already explained, the use of steam in the Edison Building has been somewhat excessive and therefore 13 hours is not surprising. It should be understood that during most of the heating season steam is kept on the building

24 hours a day, the 13 hours being simply taken as the average use of all the radiation. In some offices, windows are kept open directly above the radiators. This of course increases the amount of heat transmitted by those radiators.

Referring to Mr. Blackmore's question would say that the unit rate of transmission from the radiators is determined not by the outside temperature but by the temperature inside the room. In a building equipped with thermostatic control, if the temperature inside the room is 70 deg., approximately the same amount of steam is being condensed in the radiators per unit of surface and time during which steam is admitted to the radiators, whether the outside temperature is at zero or at the freezing point, unless the steam pressure is increased or decreased. As to my assumption of the 13 hours being high, would say that inasmuch as we have used a certain amount of steam, we could not cut down the B.t.u.'s given out per square foot of radiation, without increasing the number of hours still more; in other words, if Mr. Donnelly's figures on B.t.u. per square foot of radiation with the surrounding air at 70 deg. and the steam at atmospheric pressure are correct, then the average use of steam in all the radiators must be 13 hours per day.

Referring to Mr. Feldman's question, would say that the cubical contents of the building, exclusive of the basement are about 7,000,000 cu. ft. The pumping requirements of the building are comparatively small as the elevators are run by electricity. The two boiler feed pumps, the two vacuum pumps and two of the house pumps are operated by steam. The balance of the pumps, including one house pump, four air compressors and one vacuum cleaner are operated by electricity.

In regard to the question as to whether radiating surface includes the risers and supply piping, would say in this building the risers are all covered with heat insulation and the heating surface simply refers to the actual installed radiation.

Regarding the derivation of the formula for figuring heating requirements, would state that this is rather too lengthy to go into at this time, and that this formula is explained in detail in a book gotten out by Mr. Orr and myself, entitled, "District Heating," and is also explained briefly on page 791, Volume II, of the proceedings of the National Electric Light Association for June, 1909.

No. 402

# THE COST OF OPERATING HEATING PLANTS

By Geo. W. Martin, New York, N. Y.

Member

THE data given in this paper are from the operating records of a number of heating plants in New York City, the period covered being approximately the last five years.

Since the organization of the company, which the writer represents, the policy has been largely to effect economies by the installation of apparatus to burn No. 3 Buckwheat, which is bought in wholesale quantities and costs, delivered in the bunker, between $2.35 and $2.50 a net ton. The coal is from the Scranton district of the Pennsylvania anthracite region and runs from 12,300 to 12,900 B.t.u. and from 16 to 13 per cent. of ash. It should be stated at the outset that a poor grade of No. 3 Buckwheat has no advantage over a better grade of No. 1 or No. 2 Buckwheat, so that, unless a good quality of coal can be assured, it is useless to attempt economies by burning the smallest size of anthracite, even when it is mixed with soft coal.

In most of the cases discussed in this paper, the boiler grates were originally installed for burning No. 1 Buckwheat with natural draft. The change in the setting for burning No. 3 Buckwheat involved the building of a hollow bridge-wall with a cast iron air-box and damper set in the front of the wall at the back of the ash-pit. A motor-driven blower is set outside the boiler at one end of the bridge-wall, a hand-controlled rheostat being used to vary the speed of the blower-motor. The grates installed are of the dumping type and contain about 10 per cent. of air space. The cost of the installation of grates, motor-driven blower, rheostat, and rebuilding the bridge-wall, will average $3.00 per boiler horse-power.

Presented at the Annual Meeting of The American Society of Heating and Ventilating Engineers, New York, January, 1916.

## COST OF STEAM GENERATION

While the results obtained in a number of plants showed a lower cost of steam generation, with the use of a good quality of No. 3 Buckwheat, the writer had not until this past year made comparative tests on the different grades of anthracite marketed in New York City. In the summer of 1915, tests were made on a 150 horsepower return tubular boiler and showed that for that particular plant, at least, No. 3 Buckwheat gave the lowest cost of steam generation per 1,000 lbs.

The feed water was measured by a Worthington piston-type water meter, the steam output being measured by a General Electric steam-flow meter, while a St. John meter measured the steam for operating the boiler feed pump.

The boiler tested was in service for supplying steam for industrial purposes and during all the tests operated much under rating. The usual method of boiler testing was followed. The coal was weighed back each hour to obtain the hourly evaporation, the quality of steam was determined by calorimeter, and the flue gases analyzed at frequent intervals, the latter being of great assistance in determining the correct position of the flue damper.

In the use of forced draft, it is the writer's experience that the best results are obtained by keeping the draft balanced, that is, for any blower speed or air pressure in the ash-pit, the damper is opened just enough to carry the gases away from the furnace and through the boiler. A good method for the fireman, without resorting to the Orsat, is to hold a cloth in front of the open fire door, the cloth being just gently drawn inward if the damper setting is correct.

The use of such a system of controlled combustion is that air leakage into the boiler is largely eliminated since the draft over the fire is much reduced and much less air is drawn in through the setting..

Table I gives a summary of the results obtained in the tests, the important items being shown in the last two lines, i.e., the comparative cost of fuel for generating 1,000 lbs. of steam.

In connection with the plant on which the foregoing tests were made, extensive observations were carried on over a year's period to determine the cost of generating industrial steam during the summer and winter months. During the heating season, the steam generated is used for both building heating and industrial heating, while in summer the steam is used for industrial work only.

A clause in the contract between the building owners and the operating company specified that all industrial steam in excess of an average daily consumption of 24,500 lbs. should be paid for at cost of generation plus 5 per cent. Soon after the operating company took over the plant it was found that apparently the industrial steam used was much in excess of the amount specified. The installation of a steam meter confirmed the suspicion.

Investigation by the building owner's consulting engineer brought out the fact that the tenants were using more steam than he had estimated. The opportunity for a tenant to use more steam than he was entitled to was evident from the provisions of the leases. The largest consumer was allowed 30 horsepower, but his piping connections were found to be four ⅜-inch; five ½-inch; four 1-inch, and two 1¼-inch. While, doubtless, his original connection permitted a delivery of little more than 30 horsepower, it was found that other connections had been made as his business extended. In other cases, a single outlet of a certain size had been specified, but the connections had been extended later to additional apparatus.

TABLE 1—RESULTS OF COMPARATIVE COAL TESTS

| | No. 3 Bckwht | No. 2 Bckwht | No. 1 Bckwht | Pea Coal | Soft & No. 3 Bckwht |
|---|---|---|---|---|---|
| Moisture in coal as received | 6.9 | 8.0 | 4.8 | 3.4 | 8.3 |
| Volatile per lb. dry coal | 7.9 | 9.3 | 7.2 | 7.1 | 12.6 |
| Fixed Carbon | 76.9 | 75.3 | 75.9 | 74.2 | 75.4 |
| Ash | 15.4 | 15.4 | 16.9 | 18.7 | 12.0 |
| B.t.u. | 12423 | 12080 | 12140 | 11961 | 12944 |
| Length of tests | 24 hrs. | 24 hrs. | 24 hrs. | 24 hrs. | 24 hrs. |
| Total dry coal consumed, lbs. | 4800 | 5514 | 5171 | 5531 | 4400 |
| Per cent. ash and refuse | 18.6 | 17.1 | 17.0 | 16.8 | 14.3 |
| Total water fed to boiler, lbs. | 42988 | 46275 | 46335 | 51395 | 45045 |
| Factor of evaporation | 1.08 | 1.074 | 1.077 | 1.083 | 1.076 |
| Equivalent water from and at 212° | 46427 | 49699 | 49903 | 55712 | 48468 |
| Horsepower developed | 56.1 | 60.0 | 60.3 | 67 | 58.5 |
| Builders' rating | 150 | 150 | 150 | 150 | 150 |
| Per cent. of builders' rating developed | 37.4 | 40 | 40 | 44.8 | 39 |
| Efficiency of boiler and grate | 75.6 | 72.3 | 77.1 | 84.8 | 82.5 |
| Cost of coal per net ton | $2.22 | $3.15 | $3.65 | $4.40 | $3.15 |
| Fuel cost of 1000 lbs. steam, cents | 13.25 | 20.4 | 21.4 | 23.5 | 16.8 |
| Fuel cost from and at 212° | 12.26 | 19.0 | 19.8 | 21.7 | 15.6 |

To determine the cost of the industrial steam generated, a steam meter was placed on the line supplying all the industrial steam.

TABLE 2—OPERATING DATA OF POWER PLANT FOR YEAR 1914-1915

| Col. 1 | Col. 2 | Col. 3 | Col. 4 | 5 | 6 | Col. 7 | Col. 8 | Col. 9 | Col. 10 | Col. 11 | Col. 12 | Col. 13 | Col. 14 | Col. 15 | Col. 16 | Col. 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Period | lbs Industrial Steam Generated | Coal for Ind Steam | Total Coal Burned | Ind Coal % Total | Price Per Ton | Cost Industrial Coal | Cost Ashes Removed | Cost of Labor | Cost K.W. Hrs. | Cost Water 40cts Day | Cost Upkeep 20cts da | Total Cost | cts. per 1000 lbs | +5% | Excess Steam over 24500 lbs | Cost of Excess Steam |
| 1914 Nov. | 1034100 | 64.6 | 228.5 | 28.2 | 2.35 | 151.81 | 9.29 | 63.60 | 2.20 | 12.00 | 6.00 | 244.90 | 23.60 | 26.50 | 299100 | 79.26 |
| Dec. | 1221600 | 76.3 | 309.1 | 24.6 | " | 179.30 | 10.16 | 57.04 | 5.34 | 12.40 | 6.20 | 270.44 | 22.30 | 23.20 | 462100 | 107.20 |
| 1915 Jan | 1176056 | 73.5 | 296.8 | 24.7 | " | 172.72 | 9.62 | 57.04 | 4.10 | 12.40 | 6.20 | 262.06 | 22.30 | 23.40 | 416556 | 97.46 |
| Feb | 1076400 | 6.72 | 237.4 | 28.1 | " | 158.02 | 8.88 | 59.08 | 3.90 | 11.20 | 5.60 | 246.08 | 22.90 | 24.00 | 390400 | 93.70 |
| Mar. | 1138800 | 71.2 | 252.0 | 28.2 | " | 167.32 | 9.32 | 66.72 | 2.97 | 12.40 | 6.20 | 263.93 | 23.20 | 24.60 | 379300 | 92.92 |
| Apr. | 1164000 | 72.7 | 155.7 | 46.7 | " | 170.85 | 7.06 | 106.3 | 5.95 | 12.00 | 6.00 | 307.16 | 26.30 | 27.60 | 429000 | 118.41 |
| May | 1022000 | 63.8 | 87.3 | 73.3 | " | 153.88 | 11.65 | 169.67 | 11.54 | 12.40 | 6.20 | 365.34 | 35.70 | 37.50 | 262500 | 98.44 |
| June | 1141000 | 72.2 | 72.2 | 100 | " | 169.67 | 12.72 | 225.6 | 7.94 | 12.00 | 6.00 | 433.93 | 38.00 | 39.90 | 406000 | 161.99 |
| July | 1087260 | 77.3 | 77.3 | 100 | " | 181.65 | 10.04 | 225.6 | 9.90 | 12.40 | 6.20 | 445.79 | 41.00 | 43.00 | 327760 | 140.94 |
| Aug | 1052500 | 72.6 | 72.6 | 100 | " | 170.61 | 9.92 | 226.0 | 9.66 | 12.40 | 6.20 | 433.79 | 41.20 | 43.30 | 293000 | 126.87 |
| Sep | 892000 | 73.9 | 73.9 | 75.4 | " | 130.89 | 7.22 | 170.10 | 6.51 | 12.00 | 6.00 | 332.72 | 37.30 | 39.10 | 157000 | 61.39 |
| Oct. | 1068300 | 66.7 | 133.3 | 50 | " | 155.75 | 12.91 | 112.50 | 3.63 | 12.40 | 6.20 | 303.39 | 28.40 | 29.80 | 308800 | 92.02 |
| | | | | | | | | | | | | | | | | |

The various cost items of coal, labor, ash removal, current for blower, make-up water, and upkeep were totaled each month and divided by the steam consumption for that month.

In the summer months, when no steam was used for building heating, the total amount of each cost item was charged to the cost of industrial steam generation. During the heating season, however, as the same boilers generated steam for both industrial and building heating, the total of each item was apportioned between the two services in the following manner:

Referring to Table 2, Col. 2 gives the pounds of industrial steam as measured by meter. Assuming an evaporation of 8 lbs., Col. 3 is obtained by dividing Col. 2 by 8 and reducing the result to net tons. Col. 4 is the total coal consumed during the month for both building heating and industrial steam. Column 5 is obtained by dividing Col. 3 by Col. 4 and represents the industrial coal in percentage of the total coal.

Column 7 is the cost of the industrial coal at the price per ton given in Col. 6. Columns 8, 9 and 10 are obtained by multiplying the totals of those items for both heating and industrial service by the percentage given in Col. 5. Column 11 is an average cost extending over a year, the entire make-up being needed for the waste of industrial steam. Column 12 is an estimated figure based on a year's costs. Column 14 is obtained by dividing the total cost in Col. 13 by the industrial steam given in Col. 2. In Col. 16 is given the excess steam for the month, obtained by multiplying the specified limit per day of 24,500 lbs. by the number of days in the month.

During the summer months, or when no steam is used for building heating, the entire cost of steam generation is charged to industrial steam. The labor cost during this period is, of course, very large, as three firemen on eight-hour shifts are required since the demand is continuous for twenty-four hours and nearly every day in the year. In some plants, during the summer, the firemen might be employed at some other work in addition to looking after the boilers, but this is not possible in the plant in question.

A comparison of the cost of steam generation in a number of plants is given in Table 3. These figures were originally given by the writer in a report of the Station Operating Committee of The National District Heating Association, but they have been partially revised and extended in two cases to include operation during the whole season.

All the plants are largely for heating, hence the load is subject to all the vagaries of the weather. The low evaporation in some

of the cases is due to the extremely variable loads of the fall and spring with the attendant standby losses. For plants that are operated only a part of the year, it is impossible to maintain an efficient labor force and hence the economy suffers.

However, a high cost of 1,000 lbs. of steam generated does not always mean a high total cost for the season, for the total steam generated may be low due to proper attention to the actual demands

TABLE 3—COMPARISON OF COSTS OF STEAM GENERATION IN SEVERAL PLANTS

| Number of building | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Number of days | 15 | 365 | 5 | 4 | 46 | 227 |
| Steam generated, 1000 lbs. | 1611 | 29039 | 485 | 124 | 10310 | 47401 |
| Tons of coal, gross | 117 | 1782 | 30.3 | 11.3 | 783 | 3337 |
| Rate of evaporation | 6.15 | 7.3 | 7.13 | 4.94 | 5.89 | 6.34 |
| Avg. outside temp. | 30.7 | | 39.6 | 37.0 | 34.8 | 40.9 |
| Cost per 1000 lbs. of steam— | | | | | | |
| Coal | \$0.191 | \$0.163 | \$0.165 | \$0.238 | \$0.203 | \$0.193 |
| Labor | .049 | .093 | .079 | .251 | .052 | .063 |
| Ash removal | .010 | .009 | .009 | .021 | .008 | .008 |
| Make-up water | | .005 | | | .007 | .001 |
| Electric current, blower | .014 | .005 | .007 | .021 | .008 | .006 |
| Electric current, feed pump | | | .007 | | | |
| Supplies | .004 | .011 | .006 | .002 | .004 | .006 |
| Repairs and misc. | .004 | .004 | .002 | .001 | .003 | .002 |
| Total | \$0.272 | \$0.290 | \$0.275 | \$0.534 | \$0.285 | \$0.279 |
| Fixed charge in investment | .029 | .054 | .054 | .084 | .044 | .033 |
| Total cost per 1000 lbs. | \$0.301 | \$0.344 | 0.329 | \$0.618 | \$0.329 | \$0.312 |

of the building and hence the total cost for the season is kept at a low figure.

In several instances where the results cover a short period, the apparatus for weighing coal and water had but recently been installed. Such tests do not, of course, represent the performance throughout the year, but do convey an idea of the possible economy. In all the plants No. 3 Buckwheat coal, delivered at \$2.50 a ton, is burned with a balanced draft.

No. 1 is a 25-story office building, covering a plot of about 9,000 sq. ft. The boiler plant, consisting of two Heine water-tube boilers operated at 70 lb. pressure, supplies steam for cooking, heating

and hot-water service. The plant is shut down during the summer and the steam for cooking purchased.

No. 2 is a large 12-story loft building containing about 4,000,000 cu. ft. Steam is used for manufacturing in large amounts throughout the year, 24 hrs. a day. The boiler plant is made up of three fire-tube units.

No. 3 is a new office building 25 stories high, with a volume of about 6,500,000 cu. ft. The equipment for heating and hot-water service consists of two Erie City water-tube boilers, operated at 30 lb. pressure. The boiler-feed vacuum and sump pumps are operated by electric motors. The boilers are shut down during the non-heating season and hot water is supplied by a small heater.

No. 4 is a loft building in the old commercial section of New York. This building has only recently had supervisory service. The figures show extravagance in the labor costs and the use of forced draft in burning the coal. This case illustrates the too frequent condition where continuity of service is the only consideration given the power plant.

No. 5 is a large department store of about 15,000,000 cu. ft. contents. Four B. & W. water-tube boilers supply steam for cooking, refrigeration, operation of a cash-tube system, hot water and heating.

No. 6 receives steam from a boiler plant 750 ft. distant. The plant is operated (only when heating is required) by three B. & W. units at 100 lb. pressure. The boiler-feed water comes from a heater at a temperature well over 200 deg. F. The load conditions and the general design for this plant permit fairly satisfactory operation, as may be seen from the costs.

Figure 2 shows the costs of steam generation for building No. 6 for various amounts of steam generated. The customer is billed on the basis of readings of a meter in the building. The full line in Fig. 2 shows the costs based on those meter readings, while the broken line shows the costs based on meter readings in the boiler plant. The difference represents the loss due to condensation in the line.

## COST OF HEATING BUILDINGS

Having discussed the cost of steam generation in various types of buildings, the paper will now deal with the cost of building heating as a whole. Formulæ for estimating the amount of coal for heating buildings have been in use for several years, central station engineers probably being the first to derive the formulæ for this purpose. The writer has used two of these formulæ, i.e., that of

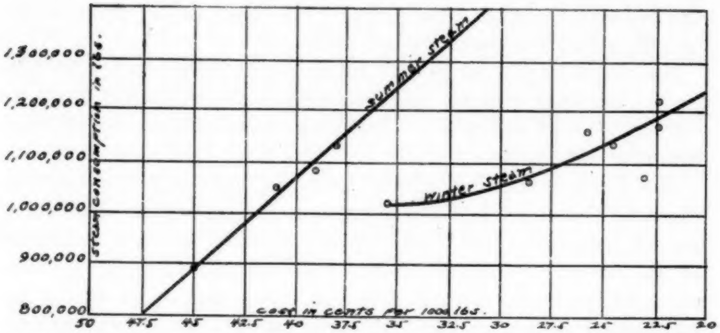


FIG. 1. COST OF STEAM GENERATION UNDER SUMMER AND WINTER CONDITIONS

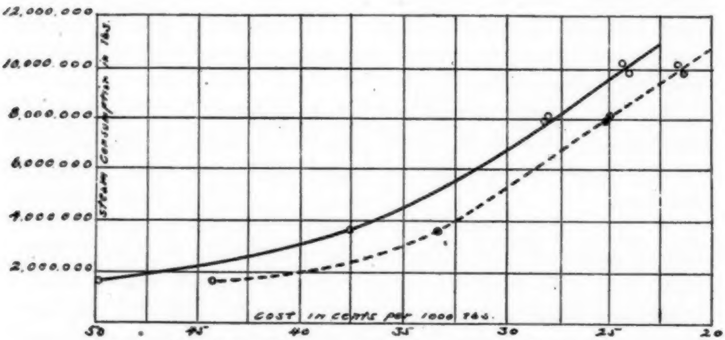


FIG. 2. COST OF STEAM GENERATION FOR BUILDING NO. 6

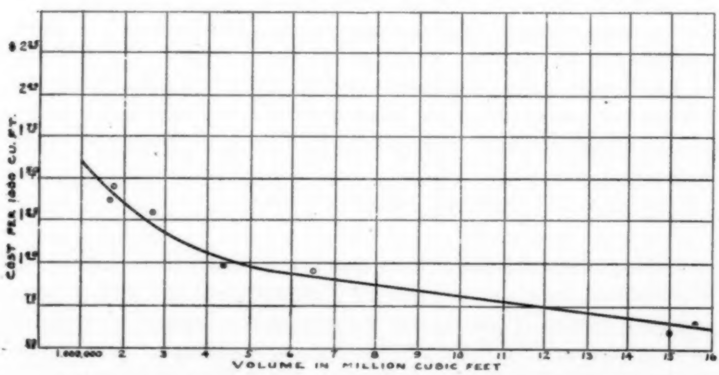


FIG. 3. COST OF OPERATION PER 1,000 CU. FT. OF GROSS VOLUME

E. F. Tweedy of the New York Edison Company, and that of D. S. Boyden of the Edison Illuminating Co. of Boston. Mr. Tweedy's formula employs the glass and wall surface, giving a value which is applied as an abscissa to a curve plotted from the results obtained on a number of buildings in New York City. The corresponding ordinate gives the tons of coal per heating season. In the Tweedy formula $\left\{ \frac{W}{4.5} \qquad \right\}$ W is the net wall surface and G is the glass surface.

Mr. Boyden's formula has been given in a paper before this Society, but for convenience in comparison, it is here reproduced. The formula is somewhat complicated, but, in the writer's opinion, it has the advantage that it takes into consideration a difference in the operating conditions in the different buildings. Experience is necessary in the use of this formula, however, as serious errors are likely to affect the variables to such an extent that the calculated result will be far from correct. The formula follows:

$$\text{Tons of coal per year} = \frac{\frac{V \times a}{60} + (C_1 \times G) + (C_2 \times W)}{C_3 \times (130 - T)}$$

$$\times L \times d \times h \times \frac{34}{e \times 2000}$$

Where:

$V$ = gross volume of the building, including basement, if heated.

$G$ = square feet of glass surface, 10% being added for north and west exposures.

$W$ = square feet of wall surface, 10% being added for north and west exposures.

$a$ = average air changes per hour during heating period.

$C_1$ = constant for glass — 1 for single glass.

$C_2$ = constant for wall, usually, .2 for brick and .3 for stone.

$C_3$ = constant for local conditions — 5.4 for Boston; 5.7 for New York.

$T$ = factor dependent upon the relation the heating plant bears to the premises heated.

$L$ = factor for portion of building not heated, or for building heated to 70 degrees F.

$e$ = average evaporation in pounds of steam per pound of coal.

$d$ = number of heating days during season.

$h$ = average number of hours of heating per day.

Under normal operating conditions, when steam is on the heating system for from 3,200 to 3,500 hours during the heating sea-

son of 7 months, the two formulæ agree fairly well with the actual results, as shown in the case of three buildings, as follows:

| Building | No. 1 | No. 2 | No. 3 |
|---|---|---|---|
| Tweedy formula ............ | 625 | 380 | 1500 |
| Boyden formula ............ | 650 | 469 | 1545 |
| Actual coal, net tons ........ | 655 | 486 | 1572 |

While the three amounts agree closely in the case of buildings Nos. 1 and 3, for building No. 2 the result by the Tweedy formula is much below the actual, probably due to the fact that much heat was wasted through leaky windows, increasing the amount of air change per hour.

Among those in charge of building operation for the United States Government, the practice is followed of assuming the condensation of 500 lbs. of steam per square foot of radiating surface per season. The writer believes this to be a safe figure, as in the case of the three buildings cited, the condensation approximated 400 lbs., 430 lbs., and 420 lbs. per square foot per season, respectively, assuming an evaporation of 7 lbs. in each case.

The writer's method of estimating the coal requirements for heating a building is to employ the Tweedy formula and check with the Boyden formula and the Government method. A comparison of the results with the known requirements of a similar building completes the process.

While the amount of coal required depends largely on the amount of exposed wall and glass surface, yet the writer has found that the total cost of operation bears a fairly well defined relation to the volume of the building.

From the results obtained over the past five years a curve, shown in Fig. 3 has been plotted showing the cost of operation in dollars per 1,000 cubic feet of gross volume. The costs include fuel, labor, ash removal, make-up water, supplies and repairs. The coal used was No. 3 Buckwheat at $2.50 per ton. This curve is not to be used as an absolute method of determining heating costs, but is rather intended as an approximation to give the consulting engineer some idea of the operating cost of a system which he designs. The buildings from which the results were obtained are all largely on direct systems, the buildings of 6,500,000 and 15,000,000 cubic feet having vacuum returns.

## DISCUSSION

W. S. TIMMIS: We are indebted to Mr. Martin for this work, for it offers data that we all need. In looking over Table 1, I notice that the fuel cost of 1,000 lb. of steam using No. 3 buckwheat is reduced to 13.25 cents as against 20.4 cents for No. 2, and 21.4 cents for No. 1.

In Table 3, I notice that he has given the results of these tests on six buildings, but only two are given for any length of time; one 365 days and the other 277 days. In these, the rate of evaporation is given as 7.3 and 6.34, respectively. This appears to check up with Mr. Bushnell's and I presume the requirements are much the same.

In the paper, where the description of the building is given, it is noted that the cubical contents are not given, nor is the exposure given in any case in either wall or glass. If these were given, many valuable deductions could be made.

The formula of Mr. Tweedy that is presented is somewhat obscure. The other formula seems to give valuable information. I think we should have a committee appointed to consider these and other formulas that are presented from time to time.

It is shown clearly that the average temperature of the heating period in Chicago is between 39 and 40 deg., and the difference between that and 70 deg. would work into a very simple formula. I think this would compare favorably with the results in this paper. I trust that we shall be able to get the missing information from Mr. Martin, so that we can have actual costs in these plants.

A formula for the coal requirements for a heating system per season might be worked out upon the following basis:

Take the sum of the heat losses from all exposed surfaces, such as walls, windows, roof, leakage and air change and divide by the average B.t.u. per ton of coal delivered as steam.

Let $A$ = cubical contents $\times$ 0.02 $\times$ number of air changes per hour.

$W$ = sq. ft. wall surface.

$G$ = sq. ft. glass surface.

$R$ = sq. ft. roof surface.

$K$ = constant for wall.

$L$ = constant for glass.

$M$ = constant for roof.

$H$ = number of heating hours per season.

D = average seasonal temperature difference between outside and inside temperatures, usually 70 deg. — 40 deg.. = 30 deg.

Z = B.t.u. per ton of coal delivered as steam under average conditions, average evaporation 6 lb. water per lb. of coal = 6 × 2,000 × 1000° = 12,000,000 B.t.u. per ton.

C = tons of coal (2,000 lb.) per season.

Then the amount of coal per season in tons can be approximated as follows:

$$C = \frac{(W\,K + G\,L + R\,M + A)\,HD}{Z}$$

With the following assumptions for average conditions:

| | | |
|---|---|---|
| 12 in. walls | $K = 0.3$ | |
| Glass | $L = 1$ | |
| Roof | $M = 0.36$ | average. |

Assuming for H a season of seven months or 210 days at 14 hours per day = 2,940 hours per season.

Assuming D = 70 — 40 = 30 deg.

$$C = \frac{(0.3\,W + G + 0.36\,R + A)\ 2{,}940 \times 30}{12{,}000{,}000}$$

$$C = \frac{0.3\,W + G + 0.36\,R + A}{136}$$

D. S. BOYDEN: I talked with Mr. Martin on this paper. I hope he will be here to-morrow. He is just recovering from an attack of grippe.

I should like to offer a little information concerning the formula that is charged against me. It says that it must be applied by some one who has had experience in the business, and that is so, to a considerable extent.

There are a number of formulas that may be applied carelessly, for instance one that I heard was from a fellow who figured 80 lb. of coal per season per sq. ft. of radiation installed. But there are others who would say 50 lb. These are only guesses, and if that is all you want you can take most anything, but if you are going to get at the cost by applying a formula to a building before it is erected, you want some definite knowledge of how to get at the radiation losses. If you do this, you will want to consider all the factors in the formula and perhaps others, to get a correct result.

This particular reprint I did not go over, but for Prof. Kent's benefit I will say that "T" is not expressed properly; it should be "transmission losses." If you had a riser in a 12-story building and the building was a long one so that the riser had to run through much space that it was unnecessary to heat, you might have transmission losses. We can, to a great extent, determine the load factor if we know something of the use of the building. For instance, if you take a large office building, you can figure that the heated space will be about 90 per cent. In factories and lofts you may figure that the load factor will be about 60 per cent.

I cannot conceive of a more intelligent way of establishing cost in advance on a building than to deal with each variable separately. We can assume that the law of averages will apply here as well as in anything else. This being the case, if you have a building with loose fitting windows, or single tight fitting storm windows, this variable will be given an intelligent value.

I should like to see, however, a standard formula presented for estimating the cost of heating a building in advance of the structure. I might even be willing to abandon this one, but I have thus far had very good results from its application.

S. M. Bushnell: Mr. E. F. Tweedy, of the New York Edison Company, has brought out the fact that when figuring coal requirements for heating service in Chicago, it is necessary to figure about twice the number of tons that are required in New York, largely on account of climatic conditions.

The formula used in Chicago when compared with the formula used in New York shows just about double the coal requirements and this will partially explain our 790 lb. per square foot per season as compared with the 400 lb., which Mr. Martin mentions. It would also explain why our costs should be higher, though why they should be so much higher per thousand pounds than those of Mr. Martin's, I do not understand.

If I am correctly informed, Mr. Martin's plants are not provided with steam meters and his figures are based largely on the reading of the water meters which show the water supplied to the boilers. These will, of course, show a higher amount than the steam meters which actually show the amount of steam delivered to the line.

Under test our 500 h.p. boilers will show as high as 70 per cent. efficiency, when operating under the very best conditions and

under full load. I would be inclined to question the efficiencies given in Mr. Martin's report on 150 h.p. boilers when operating on less than half load, as they are entirely out of line with anything which has hitherto been published. Our cost of from 35 to 40 cents per thousand pounds certainly compares favorably with the plants operated in Chicago, or we would not be able to sell steam at those figures.

I understand that the New York Steam Co. is selling steam at considerably higher prices in New York and they would

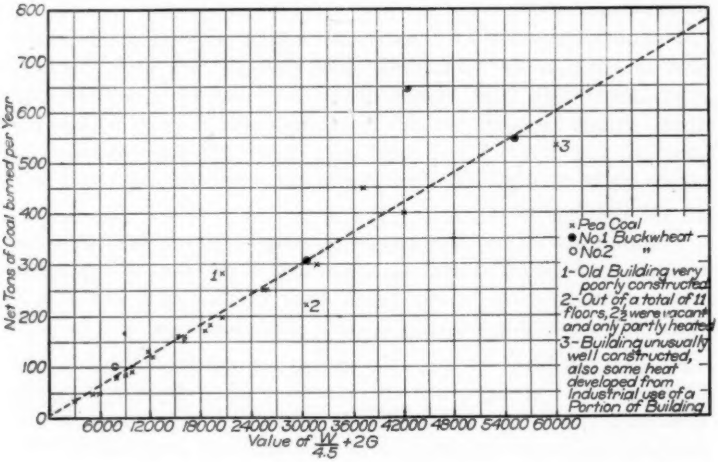


FIG. 4. CURVE SHOWING APPLICATION OF THE TWEEDY FORMULA.

probably have difficulty in doing so, if it were practicable to obtain steam as cheaply as is claimed in this report.

THE AUTHOR: Since the presentation of the paper, the writer has obtained additional information on the buildings referred to in Table 3, which, as Mr. Timmis suggests, may be of value in making further deductions:

| No. of Bldg......... | 1 | 2 | 3 | 5 | 6 |
|---|---|---|---|---|---|
| Gross volume, cu. ft. | 2,650,000 | 4,500,000 | 6,500,000 | 15,000,000 | 11,225,000 |
| Glass surface, sq. ft. | 19,000 | | 57,600 | | |
| Net Wall, sq. ft..... | 100,000 | | 145,300 | | |
| Direct Radiation ... | 28,900 | 30,000 | 52,000 | 80,000 | 28,800 |
| Indirect Radiation.. | 1,800 | | 12,000 | 4,000 | 26,000 |

The manner in which the Tweedy formula was described in the paper was not sufficiently clear, and the writer, therefore,

wishes to present the curve referred to in Fig. 4, which will make the method of application more apparent. As already indicated, the values of net wall and glass surface are substituted in the expression $\frac{W}{4.5} + 2\,G$

The resulting figure is then located on the bottom of the chart and an ordinate traced until it intercepts the diagonal line. A horizontal line running from the point of intersection over to the left will give the number of tons used per season for heating.

Some question has been raised as to the possibility of obtaining the high boiler efficiency given in Table I. An error has undoubtedly been made in the efficiency calculated for pea coal, since the per cent. ash and refuse on test was 16.8, while the coal analysis gave 18.7 per cent. of ash. The efficiency of 84.8 per cent. is, therefore, undoubtedly inaccurate, due to an error in coal analysis.

The other efficiencies given, however, seem possible under the condition of tests, though they would doubtless be impossible if the boilers were run at rating. A comparison of the steam temperatures and those of the flue gases show that very efficient operation was maintained:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Temp. Steam..... | 319.8 | 321.4 | 322.3 | 323 | 322 | 324 | 322 | 323 | 322 |
| Temp. Gases .... | 352.8 | 381.3 | 363 | 355 | 366 | 342 | 340 | 347 | 352 |

The Orsat showed high percentages of $CO_2$ throughout the tests and these, with the low flue gas temperatures, convince the writer that the efficiencies given are not improbable.

However, the tests were made merely as a matter of comparison of the different grades of steam coal and the relative values are undoubtedly as stated in the results. It is the writer's purpose, however, to repeat the tests at some future date, at which time the heat balance will be made up for each test to determine absolutely the possibility of high efficiencies under the conditions described in the paper.

No. 403

# WINDOW LEAKAGE

By Stephen F. Voorhees[1], New York (Non-Member)

and

Henry C. Meyer, Jr., New York (Member)

ALMOST all of the rules used in calculating the radiating surface necessary to warm a building, are based upon the assumption that the windows are reasonably tight. When wooden windows are used and it is found that the leakage is excessive, it is a simple matter to correct this fault by the application of weather strips. The introduction of the metal clad window, that is, a wooden window covered with metal, has caused more or less trouble in heating buildings due to the difficulty of making a tight fit between the metal rubbing surfaces, but in this case also, methods of successful weather stripping have been developed.

The all-metal window, constructed of hollow or solid section members, is a most troublesome and serious factor, not only on account of its excessive leakage, but also because of its extensive use to meet the requirements for adequate fire protection.

Several years ago one of the authors was called upon to design the heating and ventilating equipment for a building of some 5,500,000 cubic feet capacity. When it was proposed to use hollow metal windows, without weather strips, by the owners of the building, the heating engineer frankly stated that he was in a quandary as to the amount of heating surface necessary to warm the building on account of the variable, and at times, excessive leakage of windows of this type. After some discussion it was recommended that the rooms in the building be given about one-third more heating surface than would be required with reasonably tight windows, and if it was found that this increase failed to meet the situation, it would be better to

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[1] McKenzie, Voorhees and Gmelin, Architects, New York.

Presented at the Annual Meeting of The American Society of Heating and Ventilating Engineers, New York, January, 1916.

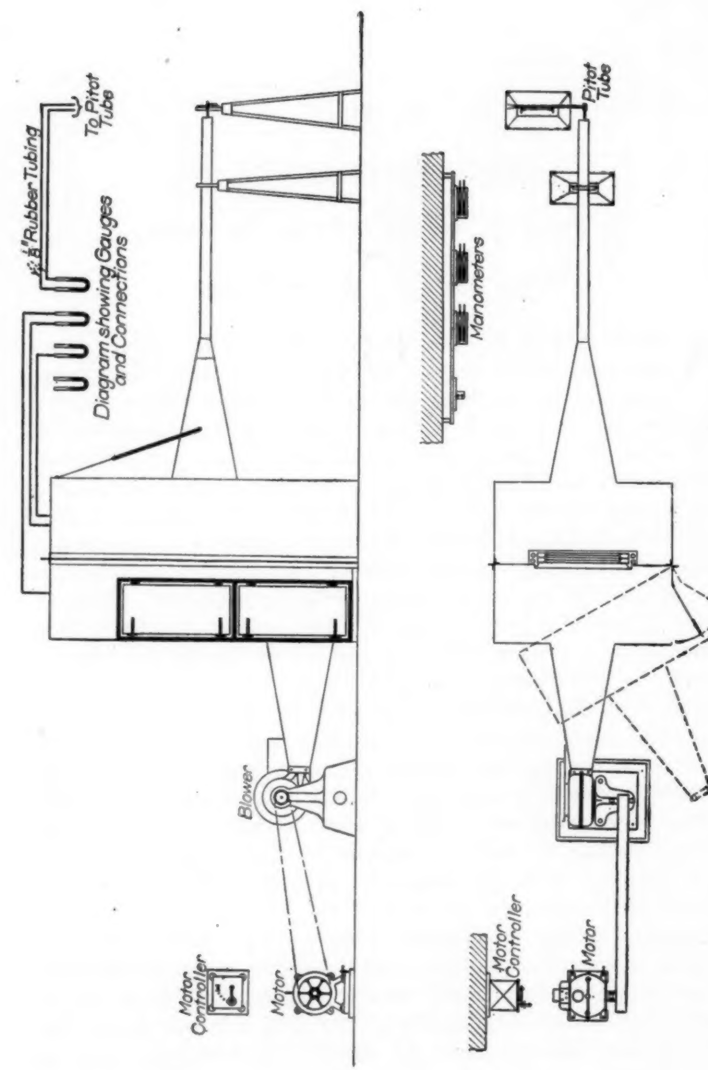


FIG. 1. DIAGRAM OF THE EQUIPMENT FOR TESTING WINDOW LEAKAGE

attempt to stop the window leakage than to add still more radiating surface. Such a course was followed and it was found that in certain parts of the building the radiation supplied was not sufficient.

In another building for the same owners, the seven lower stories were equipped with hollow metal windows and additional radiating surface was provided. The seven upper floors of the building were equipped with ordinary wooden windows made after the specifications and drawings of the architects, but with weather strips. When the building was finished, difficulty was experienced in heating the lower floors, but none whatever with the upper floors.

In all of the cases above mentioned the trouble was not experienced with all the rooms with the hollow metal windows, showing, as was to be expected, that the leakage is a variable factor. This meant that in some rooms in which the leakage was more moderate, overheating occurred and naturally very serious overheating would occur in all of the rooms provided with an excessive amount of radiation when temperatures were more moderate and with moderate outside wind velocity. This naturally produced a discomfort among the building occupants. Another interesting fact is worth recording in connection with the building first mentioned. This is exposed on all four sides and in severe winter weather, the draught from the windows along the west wall was so great and the temperatures at these points so low that it was impossible for one to sit in these locations with any degree of comfort. Along the east wall of the building, however, on the same floor and at points only forty feet away, temperatures of over 75 to 80 degrees were found, as against temperatures of 60 to 65 degrees along the west wall.

For the purpose of determining the relative merits of several methods of reducing this window leakage, the architects for the buildings mentioned, Messrs. McKenzie, Voorhees and Gmelin, began what has resulted in an extended series of experiments on window leakage. These tests have extended over a period of some twelve months and cover a large number of experiments on different types and different makes of windows, many of the windows being tested under variable conditions. When the tests were started it was supposed that practically all the air leaked through the crack between the sash and the frame and between the meeting rails; that is, it took place around the sash perimeter. It was soon found, however, that there was a very considerable leakage elsewhere than through the crack.

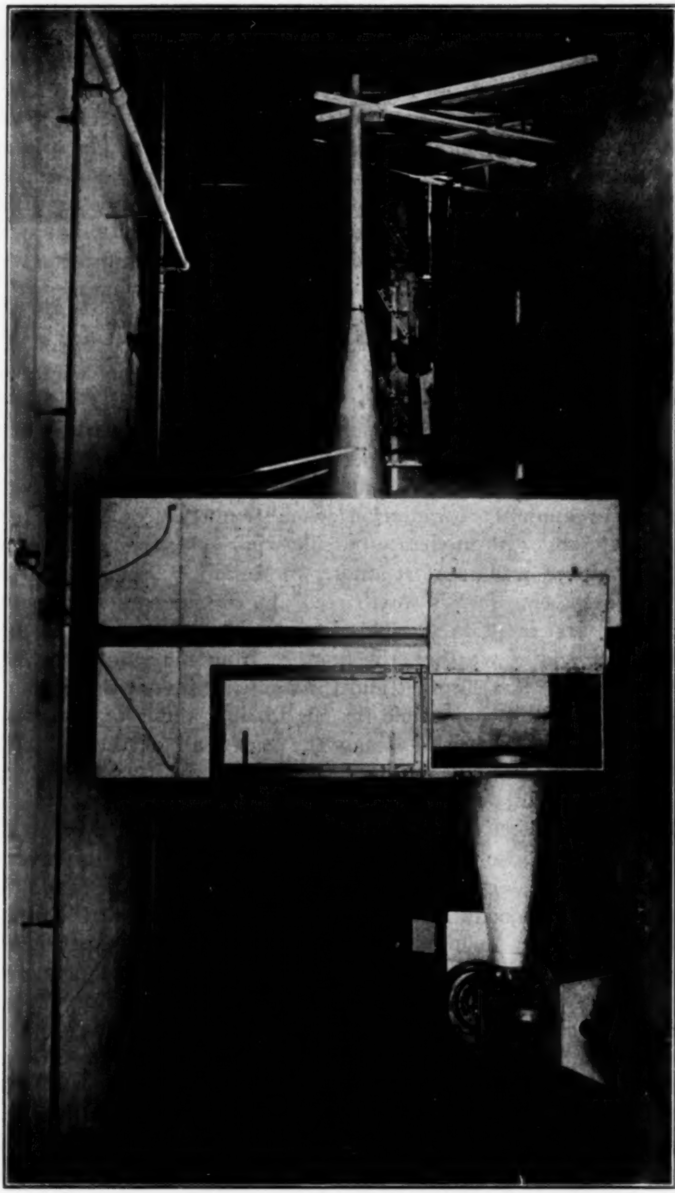



FIG. 2. GENERAL VIEW OF THE BLOWER, TESTING CHAMBER AND DISCHARGE PIPE

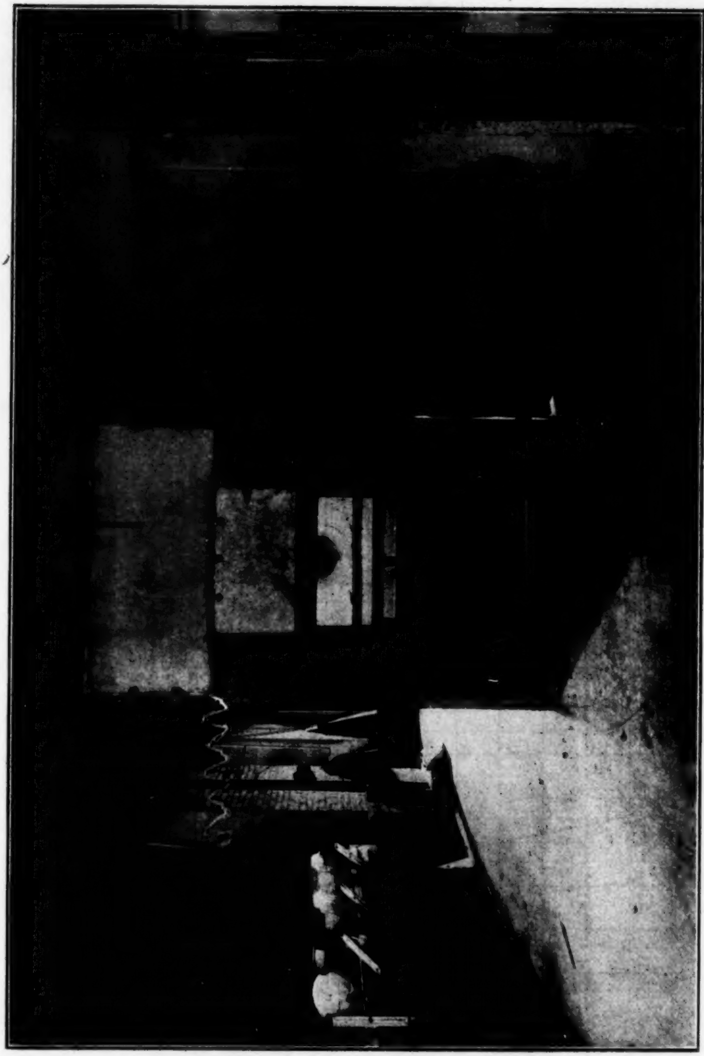

FIG. 3. INTERIOR OF TESTING CHAMBER, SHOWING METHOD OF MOUNTING WINDOWS

The air came through the puttied joints of the glass, through the connections of the muntin bars, and through the joints of the frame. Every window, therefore, was tested to determine the two classes of leakage, which are designated (1) "Sash perimeter leakage" and (2) "elsewhere leakage," the sum being the

total leakage of the window. It is proposed to give the results of some of these tests in this paper.

The tests were conducted in a space in the Chelsea Telephone Exchange Building, with apparatus purchased for the purpose,

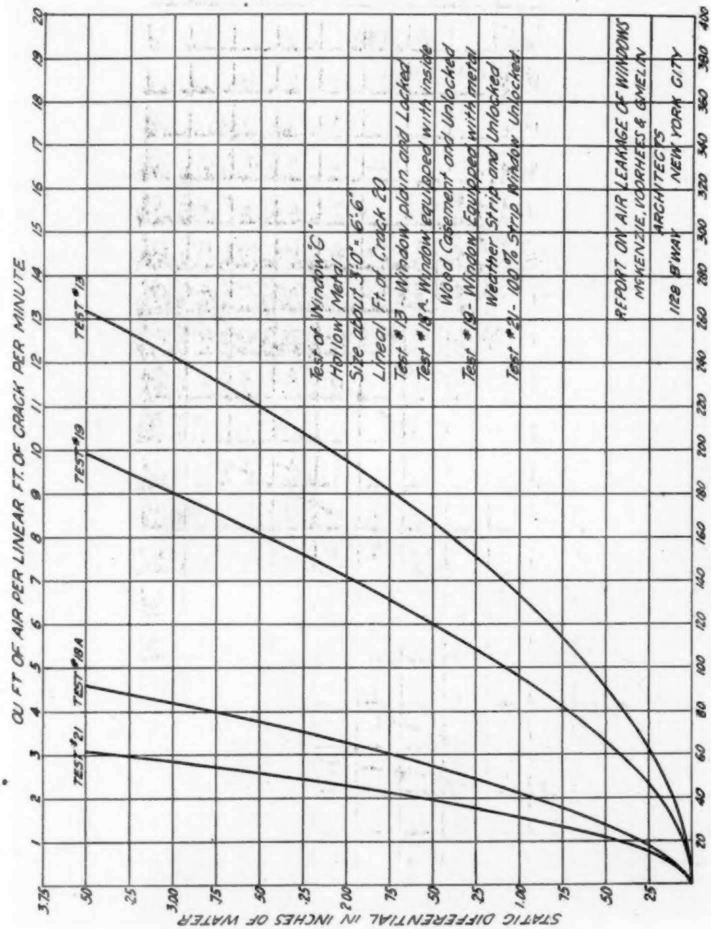


FIG. 4. RESULTS OF TESTS ON A HOLLOW METAL WINDOW

by the New York Telephone Co. This apparatus consisted of a small Sirocco type of blower belt driven by a variable speed direct current motor. The window to be tested is placed in a partition separating into two parts a chamber made of galvanized iron about 5 feet by 5.5 feet in plan and 9.5 feet high, and so constructed

as to be practically air-tight. The fan is arranged to discharge into one side of the chamber and from the other side extends a conical galvanized iron pipe terminating in a smaller pipe. A number of differential gauges are employed to record the pressure on

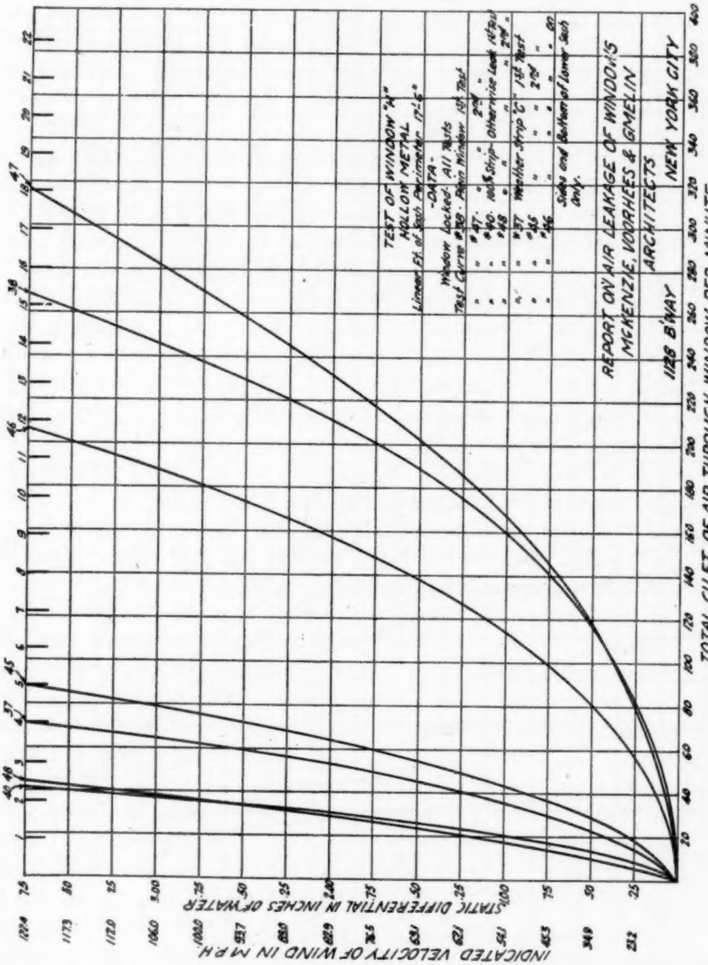


FIG. 5. RESULTS OF TESTS ON ANOTHER HOLLOW METAL WINDOW

each side of the window to be tested so that the differential pressure is obtained. Pitot tubes are employed to test the velocity of air through the discharge pipe mentioned. The quantity of air delivered by the fan may be varied by varying the speed of the

fan and by throttling the inlet, and the pressures are varied by the same means, also by sliding doors on the pressure side of the testing chamber. In each case tests were run at a number of

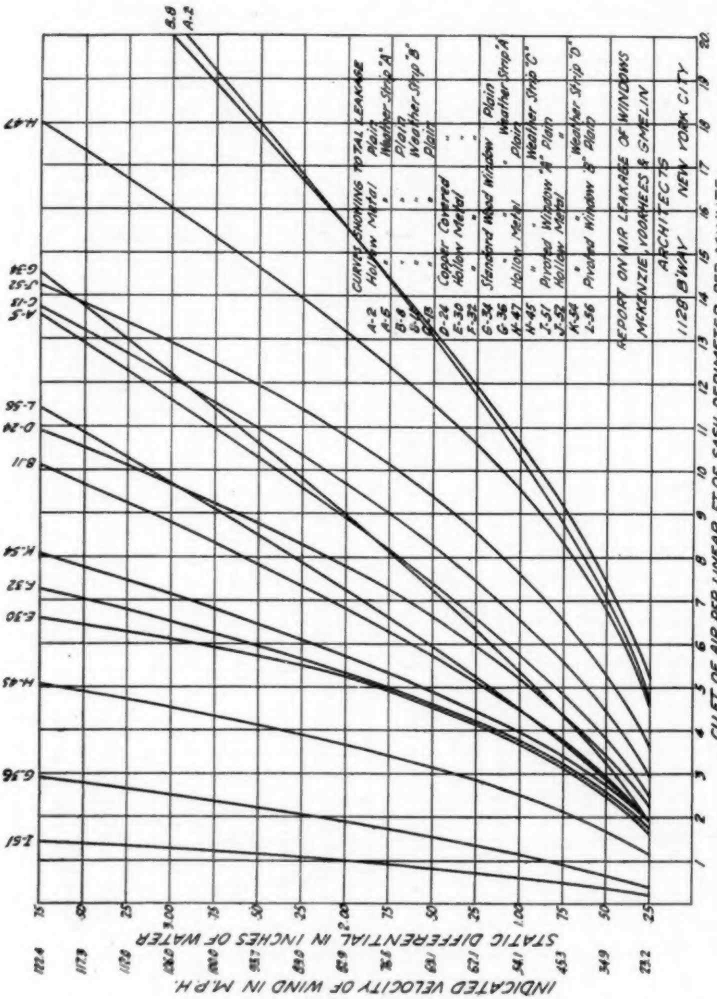

FIG. 6. SUMMARY OF THE PRINCIPAL RESULTS OF THE TESTS

different pressures and the results plotted on cross-section paper.

Figure 1 gives a diagram and Figure 2 a general view of the testing equipment and shows the blower, testing chamber and discharge pipe and the board on which the gauges are mounted.

Figure 3 shows the method of placing the windows to be tested in the chamber, the chamber being swung open on its hinges.

The general method of testing is to determine (1) the total leakage for the window as delivered by the manufacturer, and (2) to determine the elsewhere leakage by puttying up the cracks, thus eliminating the sash perimeter leakage. Deducting the "elsewhere leakage" as determined by the second test, from the total leakage, determined by the first test, gives the "sash perimeter leakage."

Inasmuch as weather stripping affects chiefly the sash perimeter leakage, the architects have also called the curve showing this leakage the "100% strip;" that is, the curve would show the leakage of a window if the weather stripping is 100% efficient. Weather stripping will reduce the "elsewhere leakage," to some extent, particularly if the upper sash is stripped on weather side, so as to prevent air from entering the pulley holes in the frame.

Figure 4, shows the results of a test on a hollow metal window "C" and gives the leakage in cubic feet per minute on the horizontal scale for varying differential pressures indicated in the vertical scale. Test No. 13 is with the window as manufactured and locked. Test No. 19 gives the test of the same window after a well known make of weather strip had been applied. At a differential pressure of one inch the leakage was reduced from 134 cubic feet to 96 cubic feet or about 28 per cent. only. The window was then fitted with an inside wooden casement and the result given in Test No. 18a was obtained. The cracks in the sash were then puttied up and the so-called "elsewhere leakage" was obtained and this is given in Test No. 21. Figure 5 gives the results of tests on hollow metal window "H." Tests 38 and 47 were with the window plain. Tests 37 and 45 were made after weather stripping was applied.

Figure 6 shows the summary of the principal results of most of the tests and gives the total leakage for the various windows tested. Figure 7 gives the leakage through the perimeter of the sash only. In both cases the leakage is reduced to cubic feet per minute per linear foot of sash perimeter. Referring to Figure 6 the poorest result is with a hollow metal window plain, that is, without weather strips. Test A-5 is upon the same window fitted with a well-known make of weather strip. Test G-34 is an ordinary wooden window without weather strips and Test G-36 is the same window equipped with a well-known make of weather strip. Particular attention is called to this test as it

represents in all probability about the leakage, perhaps a little less than most formulas for calculating radiating surfaces are intended to take care of. Most of the tests are of hollow metal windows. Test No. D-24 is a metal covered wooden window

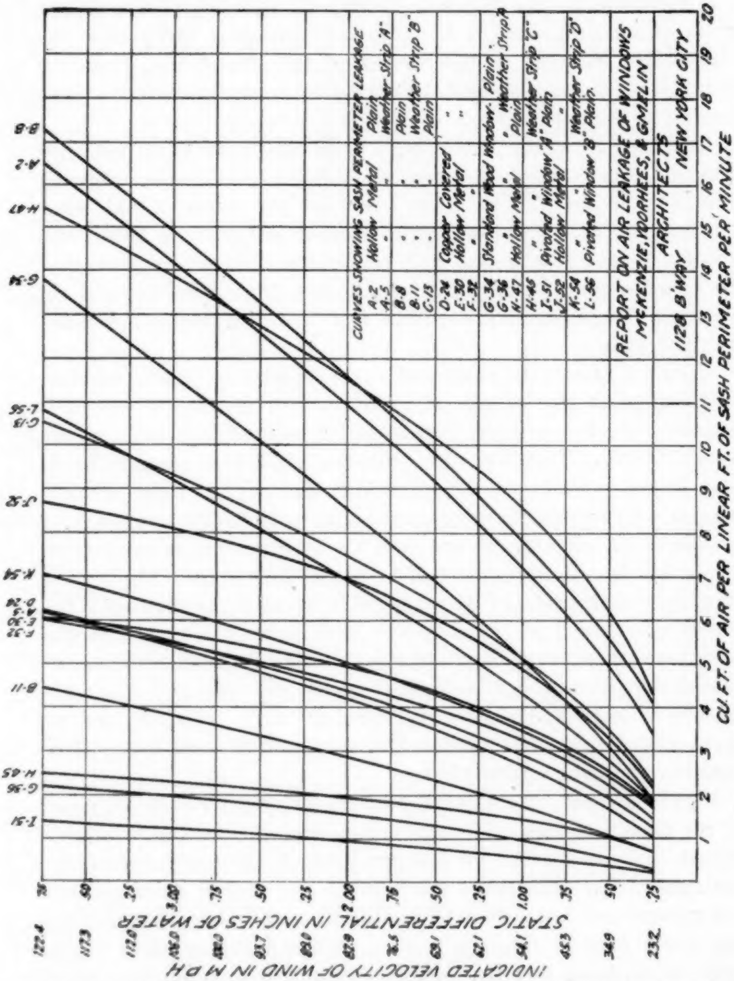


FIG. 7. RESULTS OF TESTS OF SASH PERIMETER LEAKAGE

without weather strips. Test No. I-51 is for a patented pivoted window built of solid steel sections in which the leakage was found to be almost negligible and test L-56 is upon another

make of pivoted window of solid sections where the leakage proved to be excessive.

The examination of the curves in Figure 6 will show that at a differential pressure of one inch of water the leakage through some of the hollow metal windows amounted to about 10.5 cubic feet per minute, and 1.2 cubic feet with the weather stripped wooden window, or nearly nine times as much for the former.

In endeavoring to find out what the excessive leakage meant in ordinary heating practice the author made the following calculation to find out, approximately at least, the leakage permitted by a well-known formula for determining radiating surfaces. The transmission through the north wall of a certain office building with 70 deg. fahr. inside and zero outside, according to the method used by the late Mr. Alfred R. Wolff, amounted to about 57,000 thermal units per hour and the addition to this for "exposure" amounted to about 20,000 thermal units per hour in addition, the latter being added according to the author's understanding of Mr. Wolff's rule, to warm the inleaking air to room temperature. Now the perimeter of the windows in the north wall of this floor amounted to 400 linear feet, hence we have:

$$\text{B.t.u. per hour} = \text{Per. in ft.} \times \text{c.f.m. per ft.} \times \frac{70}{55} \times 60$$

$$\text{C.f.m. per ft.} = \frac{20{,}000 \times 55}{60 \times 70 \times 400}$$

$$\text{C.f.m. per ft.} = 0.65.$$

A comparison of this apparent permissible leakage with what actually occurred in the tests shows immediately that the excessive leakage found in some of the tests cannot obtain in practice and the reason for this is of course apparent. The tests cover the leakage with certain differences of pressure. It is difficult for this to occur in practice, first, because of the oblique angle at which a wind usually strikes a building, and what is of greater moment, the improbability of maintaining any great differences of pressure on both sides of window as they are usually employed in buildings. If a window forms part of the exposed side of a closed room, for instance, just as soon as leakage begins to occur due to outside wind pressure, the pressure begins to build up inside of the room and so reduces the differential pressure that causes the leakage.

While attention is drawn to the fact that the leakage as shown in the test cannot be reached in practice in so far as actual air

movement is concerned, it is believed that the relation between the actual leakages of windows of different types is in the same proportion as in the tests noted. If, therefore, certain windows are apt to leak under severe outside weather conditions several times as much as a window that is reasonably tight, the matter at once becomes of vital importance to the heating engineer.

With a variation in the possible window leakage such that the radiating surfaces required may be any amount from the normal to several times the normal surface required with reasonably tight windows, the method of the heating engineer must become a matter of guess-work rather than the application of rules that have become more or less of an exact science. This matter is of far greater importance to the owner, however, than it is to the heating engineer, for he has to pay for the privilege of using leaky windows, the greater cost of the heating system and the greater fuel cost after the building is in use. Furthermore, the occupants of buildings so equipped have to endure the discomfort brought about by the excessive overheating in mild weather and in light winds brought about by the large amount of radiating surfaces required under extreme conditions.

What the architects who made the tests, are endeavoring to establish, is a comparative value or leakage factor for various types and makes of windows and to establish a standard of permissible leakage. It is to be hoped that the presentation of the data so far obtained, will awaken an interest in the minds of heating engineers as to the importance of the subject, and will cause them to do what they can to create the demand for tighter and more serviceable windows.

No. 404

# REPORT ON THE ESTABLISHMENT OF A STANDARD CO-EFFICIENT FOR HEAT LOSSES AFFECTED BY WIND MOVEMENT*

By H. W. Whitten, Kansas City, Mo. (Member)

and

R. C. March, Kansas City (Non-Member)

*To be Added to Co-Efficients of Heat Losses Caused by Difference of Temperature Between Outside and Inside of Buildings in Still Air.*

ASSUMING that standard interior temperature is to be 70 degrees F., wind effect with outside temperature ranging from 70 degrees to 40 degrees F. is not of great importance. Below 40 degrees it has a steadily increasing value.

A close study of the records of the Public Service Co. of Northern Illinois for the past two years, in connection with other data referred to in last year's report, has enabled your Committee to determine the wind effect on a large group of buildings of various construction.

It is obvious that the co-efficients will vary with the quality of construction in individual cases. Decrease in conductivity of walls will lower convection loss and closely fitted walls, sashes and frames will decrease leakage losses.

From the data at hand the following co-efficients have been deduced:

| | | | |
|---|---|---|---|
| 50 deg. to | 40 deg. | 1 mile per hour equals | .75 deg. drop. |
| 40 deg. to | 30 deg. | 1 mile per hour equals | 1. deg. drop. |
| 30 deg. to | 20 deg. | 1 mile per hour equals | 1.1 deg. drop. |

* This paper is part of a report of the joint educational committee of the National District Heating Association and this Society read at the annual convention of the Association in Chicago, June, 1915.

Presented at the Annual Meeting of The American Society of Heating and Ventilating Engineers, New York, January, 1916.

| | | |
|---|---|---|
| 20 deg. to 10 deg. | 1 mile per hour equals 1.2 | deg. drop. |
| 10 deg. to 0 deg. | 1 mile per hour equals 1.3 | deg. drop. |
| 0 deg. to –10 deg. | 1 mile per hour equals 1.4 | deg. drop. |
| –10 deg. to –20 deg. | 1 mile per hour equals 1.5 | deg. drop. |

For all practical purposes, the foregoing will be found sufficiently accurate for central station operation where large groups of buildings of varying construction are heated.

The accompanying tables are a daily report on the Oak Park Yaryan Heating System for the months of December, 1914, and January and February, 1915.

They show the daily B.t.u. output, the average outside temperature, the daily difference between outside temperatures and 40 degrees F., and the daily average miles per hour wind movement and prevailing wind direction.

In drawing conclusions from this report by comparing outputs on varying differences, it was found that the amount of B.t.u.'s required for this plant with an outside temperature of 40 degrees and no wind movement, was approximately 136,800,000 B.t.u.'s. This output being multiplied by the number of days in the month and the product deducted from the total B.t.u. output for the month, gives the increase in B.t.u. output due to drop in temperature below 40 degrees and total wind movement.

The total drop in temperature for the month of February below 40 degrees was 204 degrees; the increase above 40 degrees was 28 degrees. By deducting the 28 from the 204 we have 176 degrees net drop in temperature, which, added to the total wind movement of 356 miles, gives a total of 532. By dividing the increased output in B.t.u.'s, namely, 2,102,000,000 by 532 we get a quotient of 39,500,000.

It will be observed that by following the same process in January, this quotient is 43,370,000. This is due to the fact that the drop in temperature below 40 degrees was very much greater than in February.

In December the quotient is 43,600,000. In this month the variation from 40 degrees is 551 — 17 or a net of 534, which, added to 428 miles of wind movement, gives a total of 962 as against 896 in January.

The results for December and January are very consistent and show the importance of the losses caused by wind movement during cold weather.

OAK PARK YARYAN HEATING SYSTEM.

Daily Report.

December, 1914.

| Day | B. T. U. | Average Outside Temperatures | Variation from 40 deg. | Wind Av. Miles per Hour | Prevailing Wind Direction |
|---|---|---|---|---|---|
| 1 | 158,400,000 | 54 | +14 | 6 | S.W.-W. |
| 2 | 187,200,000 | 41 | + 1 | 14 | N.-N.E. |
| 3 | 208,800,000 | 34 | — 6 | 16 | N.-N.E. |
| 4 | 201,600,000 | 40 | ....— 0 | 22 | N.E. |
| 5 | 201,600,000 | 42 | + 2 | 26 | N.E.-E. |
| 6 | 216,000,000 | 39 | — 1 | 18 | E.-S.E. |
| 7 | 208,800,000 | 38 | — 2 | 14 | S.E.-N.E. |
| 8 | 230,400,000 | 38 | — 2 | 19 | N.E. |
| 9 | 259,200,000 | 32 | — 8 | 16 | N.E.-N. |
| 10 | 266,400,000 | 25 | —15 | 14 | N.W. |
| 11 | 273,600,000 | 23 | —17 | 12 | N.W.-W. |
| 12 | 259,200,000 | 24 | —16 | 14 | S.W.-S. |
| 13 | 288,000,000 | 22 | —18 | 14 | S.-N.W.-W. |
| 14 | 374,400,000 | 3 | —37 | 16 | W. |
| 15 | 352,800,000 | 8 | —32 | 13 | W. |
| 16 | 331,200,000 | 5 | —35 | 10 | W. |
| 17 | 316,800,000 | 7 | —33 | 10 | S.W.-S. |
| 18 | 266,400,000 | 25 | —15 | 14 | S.W. |
| 19 | 288,000,000 | 21 | —19 | 12 | S.W. |
| 20 | 295,200,000 | 17 | —23 | 8 | S.W.-E.-S.E. |
| 21 | 309,600,000 | 11 | —29 | 18 | S.W. |
| 22 | 324,000,000 | 12 | —28 | 16 | S.W.-W. |
| 23 | 316,800,000 | 11 | —29 | 9 | N.W. |
| 24 | 309,600,000 | 16 | —24 | 13 | N.W.-N. |
| 25 | 331,200,000 | 3 | —37 | 13 | N.-N.W. |
| 26 | 280,800,000 | 19 | —21 | 12 | S.W. |
| 27 | 352,800,000 | 10 | —30 | 12 | N.W.-S. |
| 28 | 230,400,000 | 31 | —19 | 12 | S.W. |
| 29 | 230,400,000 | 33 | — 7 | 11 | S.E.-N.W. |
| 30 | 331,200,000 | 10 | —30 | 12 | W. |
| 31 | 224,000,000 | 12 | —28 | 12 | W.-S.W |
| | 8,454,800,000 | | +17—551 | 428 | |

$$8{,}454{,}800{,}000 - 4{,}240{,}800{,}000 = 4{,}214{,}000{,}000$$

$$551 - 17 = 534 + 428 = 962;\ \frac{4{,}214{,}000{,}000}{962} = 43{,}600{,}000$$

OAK PARK YARYAN HEATING SYSTEM.

Daily Report.

January, 1915.

| Day | B. T. U. | Average Outside Temperatures | Variation from 40 deg. | Wind Av. Miles per Hour | Prevailing Wind Direction |
|---|---|---|---|---|---|
| 1 | 266,400,000 | 27 | —13 | 18 | S.-S.W. |
| 2 | 309,600,000 | 16 | —24 | 8 | W.N.W.-N.W. |
| 3 | 295,200,000 | 20 | —20 | 9 | W.SE.-W.S.W. |
| 4 | 237,600,000 | 21 | —19 | 11 | W.S.W.-S. |
| 5 | 244,800,000 | 30 | —10 | 15 | S. |
| 6 | 208,800,000 | 37 | — 3 | 14 | S.-W. |
| 7 | 288,000,000 | 27 | —13 | 20 | W |
| 8 | 295,200,000 | 20 | —20 | 9 | W. |
| 9 | 288,000,000 | 20 | —20 | 9 | W.-S.E.-S. |
| 10 | 237,600,000 | 32 | — 8 | 10 | S. |
| 11 | 223,200,000 | 36 | — 4 | 10 | S.S.W.-N. |
| 12 | 237,600,000 | 31 | — 9 | 9 | N.W.-S. |
| 13 | 230,400,000 | 31 | — 9 | 19 | S.-S.W. |
| 14 | 201,600,000 | 36 | — 4 | 11 | S.W. |
| 14 | 201,600,000 | 36 | — 4 | 11 | S.W. |
| 15 | 216,000,000 | 32 | — 8 | 10 | W.N.W.-S.E. |
| 16 | 201,600,000 | 40 | — 0 | 22 | S.E.-S.W. |
| 17 | 273,600,000 | 27 | —13 | 21 | W.-W.S.W. |
| 18 | 273,600,000 | 22 | —18 | 9 | N.W.-N. |
| 19 | 244,800,000 | 26 | —14 | 10 | W.-S.E. |
| 20 | 273,600,000 | 24 | —16 | 13 | S.E.-N.W. |
| 21 | 295,200,000 | 15 | —25 | 8 | W.-N.W. |
| 22 | 288,000,000 | 19 | —21 | 10 | N.W.-N.E. |
| 23 | 331,200,000 | 7 | —33 | 14 | N.W.-W. |
| 24 | 324,000,000 | 12 | —28 | 8 | W.-S.W.-W. |
| 25 | 288,000,000 | 15 | —25 | 10 | W.W.-W. |
| 26 | 309,600,000 | 14 | —26 | 8 | W.-S.W. |
| 27 | 331,200,000 | 8 | —32 | 13 | N.W.-N.N.W. |
| 28 | 252,800,000 | 5 | —35 | 12 | N.W.-S.W. |
| 29 | 228,400,000 | 5 | —35 | 8 | W-NW-NNW |
| 30 | 302,400,000 | 18 | —22 | 15 | S.E. |
| 31 | 208,800,000 | 38 | — 2 | 14 | S.E.-N.W. |
| | 8,126,800,000 | | —519 | 377 | |

$$8{,}216{,}800{,}000 - 4{,}240{,}800{,}000 = 3{,}886{,}000{,}000$$

$$377 + 519 = 896;\ \frac{3{,}886{,}000{,}000}{896} = 43{,}370{,}000$$

OAK PARK YARYAN HEATING SYSTEM.

Daily Report.

February, 1915.

| Day | B. T. U. | Average Outside Tempeartures | Variation from 40 deg. | Wind Av. Miles per Hour | Prevailing Wind Direction |
|---|---|---|---|---|---|
| 1 | 259,200,000 | 34 | — 6 | 27 | N.E. |
| 2 | 230,400,000 | 28 | —12 | 18 | N.E.-N.N.E. |
| 3 | 244,700,000 | 28 | —12 | 10 | N.E.-S.E. |
| 4 | 208,800,000 | 36 | — 4 | 16 | S.E. |
| 5 | 216,000,000 | 37 | — 3 | 15 | S.E.-S.W. |
| 6 | 273,600,000 | 26 | —14 | 18 | S.W. |
| 7 | 302,400,000 | 18 | —22 | 13 | W. |
| 8 | 273,600,000 | 19 | —21 | 11 | N.-W. |
| 9 | 244,800,000 | 24 | —16 | 8 | W.-N.W.-E. |
| 10 | 216,000,000 | 34 | — 6 | 20 | S.E.-S.S.W. |
| 11 | 172,800,000 | 48 | + 8 | 20 | S.W. |
| 12 | 201,600,000 | 39 | — 1 | 13 | N.E. |
| 13 | 136,800,000 | 50 | +10 | 14 | S.E. |
| 14 | 194,400,000 | 40 | 0 | 22 | S.W. |
| 15 | 244,800,000 | 32 | — 8 | 15 | S.W. |
| 16 | 230,400,000 | 27 | —13 | 6 | W.S.W. |
| 17 | 201,600,000 | 32 | — 8 | 7 | E.-S.E. |
| 18 | 187,200,000 | 37 | — 3 | 8 | E.-S.E. |
| 19 | 187,200,000 | 38 | — 2 | 6 | E.S.E.-E. |
| 20 | 151,200,000 | 42 | + 2 | 6 | E.-S.E. |
| 21 | 172,800,000 | 45 | + 5 | 7 | S.E. |
| 22 | 172,800,000 | 39 | — 1 | 6 | S.S.E.-E.N.E. |
| 23 | 172,800,000 | 43 | + 3 | 12 | N.E.-S. |
| 24 | 194,400,000 | 34 | — 6 | 12 | S.W.-W. |
| 25 | 216,000,000 | 29 | —11 | 10 | N.W.-N.N.W. |
| 26 | 223,200,000 | 26 | —14 | 10 | N.W. |
| 27 | 201,600,000 | 31 | — 9 | 13 | N.W.-N. |
| 28 | 201,600,000 | 30 | —10 | 13 | N. |
| | 5,932,800,000 | | +28—204 | 356 | |

Average B.t.u. at 40°, no wind=136,800,000x28 days=2,830,400,000.

5,932,800,000 — 3,830,400,000 = 2,102,200,000

$$204 - 28 = 176 + 356 = 532 ; \frac{2,102,200,000}{532} = 39,500,000$$

# JOINT DISCUSSION OF PAPERS

on

# WINDOW LEAKAGE

By S. F. VOORHEES AND H. C. MEYER, JR.

and

# STANDARD FOR HEAT LOSSES AFFECTED BY WIND MOVEMENT

By H. W. WHITTEN AND R. C. MARCH

F. K. DAVIS: In the discussion of these two papers, that of Mr. Meyer is first. We cannot very well go beyond the returns of a report when they are so complete as in Mr. Whitten's paper.

I had the pleasure of being present at a number of these tests and helped in a small way with some of them, and so I can say positively that every precaution was taken that they would be accurate. They were checked up in every possible way. I had hoped to get some comparisons from these tables to work up a comparative formula to present at this meeting, but unfortunately the last ten days I have had to spend mostly in traveling, and I have had to study the paper as best I could on the trains, hence I have been unable to get myself properly prepared.

Any formula for figuring radiation to take care of window leakage has the factor $x$ in it, but I think the general formula for glass should be more nearly 3 than 1. Personally, I know that about 60 per cent. of the office buildings in New York are in trouble at various times with their heating, much of the trouble being due to this question of air leakage. The question of weather strips on wooden windows is simple, but when you come to the problem of weather stripping metal windows, it is not so simple. It is not only the initial stripping that must be thought of—the life of the stripping must be considered. I know of a building in New York that was weather stripped five years ago. The cost was something like $4,500 and within the last six months it has been necessary to spend about $2,300 in repairs. This is a factor that should be considered before the windows are selected.

For the past eight or nine years, until last January, I spent the greater part of my time in checking up window leakage. I believe I have made more practical experiments along this line than almost any one else, and the tests have been on all kinds

of buildings, residences, office buildings, warehouses, etc. In the beginning a certain set of figures were given to me but I soon found that I was incorrectly informed. After about the first application of these figures, I found that they were wrong, so I had to cut and try. On 60 or 70 buildings, the cut and try methods got us nearer to the danger point than we should have gone, but in most instances we were successful. One I remember was where a hot water job was proportioned as one foot of radiation to two of glass equivalent. The heat loss was small and the result was that the house was overheated most of the time, but the owner was able to heat the building with a water temperature of 135 deg. instead of 180 deg.

The question may be raised whether the heating of a building can be successfully accomplished with the ordinary factors when the window leakage is excessive. Sometimes it may work out all right, but if the leakage is excessive as the tables show, then the radiation factors as generally used are insufficient.

I know of an instance where the condensation from the radiators was about three times as much as usual. Under ordinary conditions the trap should have discharged once each minute, but when heat was first turned on the cold building, the trap discharged three times per minute, or somewhat less than 20-second intervals, hence the trap was unable to take care of the condensation. Water backed into the return pipes and there was trouble. Starting with a cold building you have three times the condensation that you have when a building is warm. This might have some bearing on the point.

This is a problem that must be investigated further, until we find the relation between the outside wind velocity and the pressure inside of different types of buildings. Whether that will be easy to ascertain, I am not prepared to say at the present time; what the tests have shown, as Mr. Meyer has stated, is purely comparative and in comparing the results as shown with the results in other buildings that have wooden windows, I know that the differences must be due to the windows only.

All our rules now take into consideration the cubical contents of a building. I think the ideal rule for determining radiation will be one based on wall surface, glass surface and window leakage; not based on cubic contents and wall and glass surfaces. Cubic contents should be neglected. I have used a rule on this line and have obtained very satisfactory results, far more accurate than any rule in which cubic contents enters into the calculation.

Passing to the paper of Mr. Whitten, there are some things in it that I do not understand. They may be perfectly clear to the author but not so to me. I find on the first page that where the temperature varies from 20 deg. to 10 deg. Fahr., for each additional mile of wind velocity, the equivalent drop is 1.2 deg. On Monday of this week I noted that the Weather Bureau stated that in the recent cold spell the temperature was 10 deg. and that there was a wind movement of 42 miles. In that case, if we take the factor 1.2 and multiply it by 42, it would give us a temperature of something like 30 deg. below zero. This is manifestly incorrect. It might be more under certain amounts of leakage, but not with the average leakage, because if the temperature goes down to zero with a high wind movement, the result will be ridiculous. I think we might be given a little information on this point. There is a co-relation between wind velocity and temperature, but I do not think we gain anything by adding them together. Rather we should take the different temperatures and wind velocities, and co-relate them, but we should not attempt to figure wind velocity for a month and add it to the total drop in pressure for a month, because it would not give us anything that would be reliable.

R. P. BOLTON: The subject of air leakage has more than one side, and such leakage is not always a disadvantage. It is simply a question of how you consider it, whether it is a question of cost of operating the heating plant or that of the health of the occupants. As buildings are now heated, the people who occupy them would probably be asphyxiated within a short time if there was no leakage of air, for the reason that they shut themselves up, the windows are closed, the heat is turned on, and the humidity is reduced; for these reasons window leakage is desirable, particularly in the present-day apartment house.

The question of operating cost largely concerns the landlord, who has to pay for the steam that supplies the heat necessitated by this leakage. In view of the fact that the modern method is to have plenty of ventilation, and nearly every one has regard for ventilation in these days, at night especially, the easiest way for the tenant is to open the window and turn on the radiator, which is rather hard on the landlord who does not like to heat the whole outside and he does deserve a little consideration.

With these points in mind we might consider these papers from a standpoint that window leakage is not altogether a

disadvantage, even in office buildings, and particularly is this the case in loft and apartment buildings. It is true that for years we have assumed a standard amount of leakage to be taken care of; due to the changes that have come in construction, and most of us have seen the varying changes to the substitution of metal windows for wooden ones, a new method of figuring must now be devised to take care of this change. The old method has passed, and I believe that there are but few engineers who have not experienced some trouble through shortage in heating surface, because they had applied old rules to modern construction.

It is fortunate for us that we are in a locality where we do not have to bother about wind velocities, especially some of the velocities that prevailed when this paper was written. If such a wind prevailed here in New York, I am sure that some of our skyscrapers would blow right over. The average velocity here, as shown by the records, is 8 miles per hour. Occasionally we suffer from a comparatively high wind velocity accompanied by a low temperature. It is under such conditions that the modern office building Mr. Davis mentions, finds a shortage of heat. An instance of the kind occurred the other day when we had a wind velocity of about 20 miles an hour with a temperature of 13 degrees; this brought forth a number of complaints. Last week we had a similar condition of high wind with low temperature, which produced the same results. High winds do not always accompany low temperature; in fact in New York, when we reach the near-zero mark, it is almost always accompanied with still air.

Referring to the paper of Messrs. Voorhees and Meyer, you will notice that with a wooden window not weather stripped, you get about five times the amount of leakage that you do when it is properly weather stripped. This is a very important statement and one in which we should be greatly concerned. We should not be blamed for inadequate heating of plants, when we take a set of plans that have been drawn by those who are supposed to know more about windows than we do, and we provide heating in accordance with the plans, as shown; we have a right to assume that we will have first class construction to deal with.

We make our plans accordingly, and later there comes a time when we find the construction which we naturally assumed would be proper, is very defective, and our heating surface insufficient.

Frequently the leakage that occurs through the openings around a window is appalling. In my experience, I have found that there is nearly always a substantial amount of leakage also between the window frame and the plaster. Such conditions are inexcusable, and we should certainly be right in holding the architect or builder responsible for such defects. I know of a building where several thousand dollars had to be spent after its completion in stopping up holes and cracks. In some of the rooms one could stand in a certain position and get a bird's-eye view of the city under the window sills. I think we have good reasons to call the attention of the architects and manufacturers of windows to the poor construction that we often encounter.

It seems strange in this age of information, that so very little is apparently known as to how windows should be set. The window was the elementary form of keeping the elements out of man's habitation, and has been under construction for some 500 years—yet to-day many of them are made about like the old first style of windows.

One element in connection with this subject of air leakage that has not been dealt with is the subject of inward drafts in a building. In the 30-story building in which I occupy offices, we get an extraordinary wind velocity across the room every time we open our transom into the hall. The elevator shafts seem to be open conduits that carry air up through the building. Any time we want it we can have a lively breeze through our office, without any regard whatsoever to outside wind movement, just by opening our transoms. In hotels and office buildings this is not at all a bad thing, but it is rather an advantage in some ways, in furnishing ventilation.

Another point is the extreme difficulty in properly tabulating the relation of heating to wind leakage. "The wind bloweth where it listeth . . ." and the building stands where it is put and it gets the wind from every direction. We find great trouble in co-relating wind movement with heating requirements. I have endeavored to bring together some observations of this nature on municipal and other buildings during the year. The steam used for heating, and the varying wind velocities were carefully observed, but there was no relation that we could find. There must be an affinity between wind movement and heating a building, but they are difficult to establish.

I wish the tests given in the paper which have been thoroughly gone into could have been conducted at lower static differences than those shown on the diagrams.

In referring again to Mr. Whitten's paper, I think I have to agree with Mr. Davis. The method by which Mr. Whitten has chosen to derive his conclusion is not, to my mind, a scientific one. I do not think we can properly take two such unrelated elements and add them together and then use them as a factor. I think this will be accepted without question by all.

FRANK IRVING COOPER: I should like to add a word to what Mr. Bolton has said in relation to building construction.

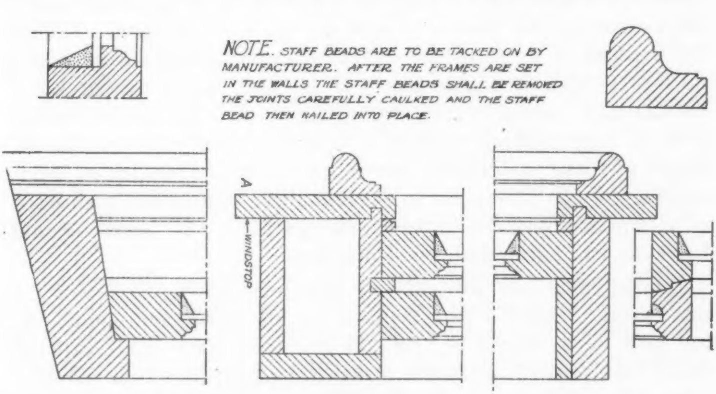


FIG. 8. SPECIAL WINDOW BOX CONSTRUCTION TO PREVENT AIR LEAKAGE.

I agree with him but there is one point about the construction of windows concerning which the engineers should make a stipulation. They should have a clause in their contracts that their guarantee is based on the building being properly constructed. That would remove much blame from their shoulders when the questions of leaky windows are discussed.

I should like to illustrate the usual form of window boxes, and tell you how I overcome some of the difficulties of air leakage around window frames.

In my specifications I require that the staff bead be taken off before the final coat of paint is put on and the joint packed with some form of plastic cement, then the bead to be replaced and nailed tightly in place. There is usually no objection to this being required in the specifications. Then the frame has this extra projection, A, of the face piece of the box, see Fig. 8.

This does not increase the cost to the contractor, if the question comes up when the contractor is getting estimates; the mill is usually so anxious to get the order that they will supply the window frames with the staff bead tacked on and the extra width of face without additional cost.

When the frame is placed and the mason does his work the brick and mortar is brought right up around it with the result that this joint is covered. We have found that this method of construction makes a great decrease in the leakage of air around windows.

J. J. BLACKMORE: Just a word about this paper of Mr. Whitten. This is a report with a view to establishing a standard, and I think some of the figures should not go unchallenged. Taking his method of figuring the effects of wind leakage you would find that with a temperature of 30 deg. accompanied by a 50-mile gale, would require one to figure on a basis of 25 below zero in apportioning radiation, which we know is erroneous. Much of these calculations savor too much of commercial engineering. I raise the point to prevent these figures being adopted as a standard, without further investigation. The figures should be revised to agree with good practice.

I hope some one will take up the question in the topics for discussion. There is no standard for allowance for wind leakage and there should be one. If engineers have made calculations that provide for wind leakage we have not been advised of the fact. There are also two other questions that should be discussed, viz.: the extra leakage of the north and west side windows, and the average window and door leakage of a school building.

W. H. DRISCOLL: I think the Society is greatly indebted to Mr. Voorhees and Mr. Meyer for the time and labor they have spent in the preparation and presentation of this paper. The information given points the way that will lead the engineer out of the darkness in which he has been groping, into the light where he should be. We have been making radiator calculations on the basis of heat losses through walls and windows and the factors used are generally uniform, but in making allowances for air changes, or leakages, while we do not like to admit it, it has been largely a matter of guesswork, and this is a custom which must be abandoned. I think the Society should take up the subject of this paper and either extend the investigation, or establish from these results a standard that can be generally used.

We have no standard at present—we match one formula against another; every engineer has his own individual method and is governed by it. I know that there is a great difference of opinion between the ideas of the various engineers right here in New York. By using the various methods for figuring there is shown a difference of perhaps 50 per cent. in the amount of radiation that they would figure for a building.

On one occasion I had some work in connection with a building where we had to take up the question as to whether we had sufficient radiation or not. I thought we had not and inasmuch as there was a certain responsibility for the proper heating of the building I endeavored to argue the case. I took the question up with the architect and his engineer. We had a conference and threshed around on the subject for hours. We compared our formulas but neither the architect's engineer nor myself could back our formulas up with the formula of any recognized authority. The architect was the sole judge and naturally favored his own engineer, and the amount of radiation as shown on the plans was installed. When the building was completed the rooms on one side were all right; those on the other were all wrong and additional radiation had to be installed in them.

The west side of the building had hollow metal windows and the heating of the rooms on that side was not satisfactory. The "elsewhere" leakage that Mr. Meyer mentioned was greater than anything that could have been determined beforehand without experience with the same kind of a building.

After the building was completed and occupied I had occasion to spend some time in it and took a room with an eastern exposure. It was quite large and had two windows, and yet in zero weather there was no time when I could not work there in my shirt sleeves. On the other side of the corridor there was a smaller room fitted up with hollow metal windows, and it was always cold, usually somewhere about 60 deg. and they had many complaints about it. The room was occupied by two ladies who conducted a hair dressing parlor and they had many lady visitors; the windows were hung with lace curtains. When the ladies found they were unable to get sufficient heat they opened the door into the corridor, which only aggravated the condition and the curtains stood out at an angle of almost 45 deg. After we had caulked up the windows it was somewhat better, but even then the curtains stood out because of the "elsewhere" leakage around the edges of the glass.

I think this subject is of the utmost importance to the members of the Society, and I believe the Council should take into considera-

tion the possibility of appointing a committee for continuing these investigations further.

A. K. OHMES: Mr. Meyer states in the paper that, "it was decided to give the rooms about one-third more heating surface than would be required with reasonably tight windows." I should like to ask Mr. Meyer how the ordinary radiation was figured.

Mr. Meyer refers to figuring up in accordance with Mr. Wolff's rule. Now the rules of Wolff are those of 22 years ago and it was found, immediately after they were put out, that the co-efficients were not right for our work. I should like to know if Mr. Meyer has any objection to stating the co-efficient that he uses, based on these rules. I am somewhat familiar with this subject, and should like to know exactly how the co-efficients used were obtained.

H. C. MEYER, JR.: I am sorry that I cannot answer Mr. Ohmes' question, at least not very definitely. We used Mr. Wolff's work as a basis and modified it as we thought best for our work. That is the only reason why I speak of it. We usually add to his transmission loss about 30 per cent. for northwest exposure, and that is the factor that I used in this case. I do not think that I stated that we used the rules exactly, but simply as a basis, for all the work in our office. If we have walls particularly exposed we add; if the room is situated under exposed conditions, we also add to these rules.

R. P. BOLTON: We are using in our office what we believe is a very conservative figure. We figure 1.5 cu. ft. of air per minute per foot of sash perimeter. If you will refer to Fig. 6 of the paper, you will notice that my factor corresponds very closely with the showing of curves G-36, and H-45.

J. A. DONNELLY: I think there have been some very valuable suggestions in regard to what we might or might not do. The most valuable is that it might be possible to bring about some changes in engineers' specifications. I think the Society might benefit if Mr. Meyer would give us a list of some of the changes he has made in his specifications. The idea seems to be prevalent that the Society has never recommended anything as a standard clause in a specification, and we know that it is so. I think the time has come when we should receive as a Society, and offer to the engineers, some standard clause, developing quite some progress by the addition of a clause each year.

We find trouble not only with leakage of air around windows, but under gables, piazza porches, and even under roofs. I believe that the study of window leakage might result in some statement in a specification that the window leakage should not be over a certain amount. It might be difficult to arrive at this, but it would result in it not being necessary to make more than one or two tests of a particular window to decide whether it was in accordance with the standard window leakage.

I have always been interested in the subject of which Mr. Bolton speaks as "popular ideas of ventilation." It does seem regrettable that the usual idea of how best to obtain ventilation, in the layman's mind, is to open a window. You will find that all advertising matter concerning ventilation that is published, other than in our own trade papers, has to do with the putting of a disc fan in a window or a piece of wood under the lower sash. This may result in ventilation of a kind, but we prefer the kind that has additional apparatus for warming the entering air.

Proper publicity work on our part, explaining in a non-technical manner our method of combined heating and ventilating should result in a preference for our apparatus, and results, over those obtained by the "Ventilation" man who does no heating.

Stephen F. Voorhees: I am very glad to hear the discussion of the tests described in this paper, because I am seeking all available information on the subject. In the building referred to, we failed to obtain proper heating results, and we determined to find out the cause, particularly as the heating surface was much in excess of the usual amount. Our aim was to make the building habitable. Our first step was to determine the best method of making the windows weathertight, and that problem has been solved by the installation of weather strips. But the second and most important step in this work is to bring the hollow metal window manufacturers to a realization of the fact that better windows are needed, so far as leakage is concerned. This means that we must create a demand in the market for better windows. We believe that eventually we will have windows which are reasonably weathertight, although they will be more expensive than the hollow metal windows now on the market.

But to speak about the tests: We were surprised to find that the elsewhere leakage is particularly high in some hollow metal windows, being as much as 50 per cent. of the sash perimeter leakage. Some of this is undoubtedly due to poor glazing.

The members of the sash are hollow and there is a big leakage around the joints of the muntin bars. The wind gets in around the glass and travels through the hollow members until it reaches the open joints on the inside, the inside muntin caps being loose for glazing. By taking care to thoroughly bed the glass, a large amount of this leakage can be eliminated.

We are now trying to determine an ideal leakage curve, realizing that an absolutely airtight window is neither necessary nor financially practicable. If you will refer to Fig. 6 in the paper, you will see what can be done by good weatherstripping, as shown by curves G-36 and H-45, the former showing the total leakage of a first-class wood window, weatherstripped, and the latter a hollow metal window of the type installed in the building referred to, after weatherstripping. We have just completed the weatherstripping of some 300 windows on the northerly and westerly sides of this building, and the results, thus far, indicate that the leakage trouble has been cured. We believe, therefore, that the ideal leakage curve is somewhere between curves G-36 and H-45. Our present effort therefore is to persuade the metal window manufacturers to make a window whose leakage curve will fall inside this ideal curve.

I think before we complete all our tests, we will be able to improve the leakage curves on many of the windows already tested. The manufacturers, many of them, are alive to the disadvantage of the hollow metal windows from a leakage standpoint, and are willing to co-operate to improve them. For example, we have recently completed the test of another window of the same type as C-13, and it has been greatly improved by a few minor changes, without increasing its cost.

If the engineers will urge the need of reasonably tight windows, I think it will tend greatly to improve the whole industry, with benefit to the owner as well as to yourselves, by not having him suffer from inadequate heating. For this he usually blames the engineer, because sufficient radiating surface was not supplied, but which is really due to faulty window construction.

D. M. QUAY: As I stated last night, it is necessary to consider air leakage in any kind of heating problems. We have been taught to consider cubic contents as a factor, and most of the rules that we have had used the cubical contents as a factor with the glass and equivalent. This brings up the question of how much air leakage is to be allowed for. I am strongly of the opinion

that instead of considering this factor as contents we must consider it as "air leakage" because the air leakage very materially affects the contents and makes it necessary for *it* to be considered.

H. C. MEYER, JR.: There is very little to say except that I do not think that we have given enough credit to Mr. Voorhees for the work he has done. The work was all his—I simply brought it before the Society.

I do not consider that radiating surface is at all involved with cubic contents. I pay no attention to cubic contents with rooms of ordinary dimensions. In some classes of buildings, of course, it must be considered; stores and churches, for instance, where it is necessary to make provision for a certain amount of heat to warm the air after the building has been standing without heat. Personally I do not think that the factor of cubic contents amounts to much.

Mr. Donnelly's question as to a standard specification from our office, I do not quite understand. Certainly a specification has nothing to do with a method of calculating surface. An answer to Mr. Ohmes' question might cover Mr. Donnelly's, in a general way. Would it not be an interesting undertaking to take a floor of a building and have a number of engineers work up the radiation required in their own way and see what the results would be. Have Mr. Ohmes and Mr. Baldwin and Mr. Carpenter and as many others as are interested do this, as a comparison of methods.

About the suggestion of a committee, it seems to me that when anything comes up that is not clear, the Society appoints a committee on the subject. I do not think that this is a matter for a committee at all. There is only one thing to be done and that is we must insist on having tight windows, and a committee will not bring that about. The work that Mr. Voorhees is doing is in the line along which this work must be conducted.

No. 405

# TESTS ON THE RECIRCULATION OF WASHED AIR

By G. L. Larson[1], Madison, Wis.

Non-Member

## INTRODUCTION

IN the light of more modern studies in ventilation it would seem that the real explanation of the ill effects of bad ventilation is not to be found in the chemical composition of the atmosphere breathed. The long debated idea that expired air contains organic matter which is toxic has been abandoned by most physiologists.

The various phases of the chemical composition of air were discussed some time ago in a symposium on ventilation at the Chemist's Club in New York City.

There is unanimity among them regarding the chemical vitiation of the air. Pure air contains nearly 21% of oxygen. This may be reduced to 17%, a proportion too small even to support ordinary combustion, before its diminution becomes harmful. Except in extreme conditions the amount of oxygen in the closest halls crowded with people practically never falls below 20%. Oxygen will therefore take care of itself and may probably be wholly left out of consideration in ventilating systems. We are reminded that it is necessary to go only a short distance up into the mountains to come under an atmospheric pressure such as to reduce the oxygen supply much more than it is reduced in crowded assemblies, and yet mountain air is especially healthful.

The air, under usual conditions, contains about 4 parts of carbon dioxide per ten thousand parts (0.04 per cent.) and the "standard" of desired purity for the air of dwellings was long ago placed as low as 6 parts per ten thousand. Experimentation in-

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Presented at the Annual Meeting of The American Society of Heating and Ventilating Engineers, New York, January, 1916.

dicates, however, that it does not become harmful to man until the carbon dioxide accumulates to above one per cent., or nearly forty times its usual amount. The air in crowded rooms very rarely reaches 0.4 per cent., so that evidently a quantity of carbon dioxide far exceeding the highest hygienic limit which has hitherto been set up as a "standard" can be breathed with impunity. It has also been stated that the bacteria in the air need not be considered in the problem of ventilation, since the comparative unimportance of the air as a vehicle of infection is becoming widely recognized. (See Journal of the American Medical Association, "The Air as a Vehicle of Infection." Feb. 7, 1914, p. 423.)

In contrast with all the foregoing negative factors with respect to the discomfort or ill health hitherto associated with inadequate ventilation, we may now conclude with reasonable certainty that the symptoms of discomfort in a badly ventilated place are due to the physical condition of the air with respect to temperature, humidity and movement, and not to any chemical properties whatever. (The Journal of the American Medical Association, Nov. 7th, 1914.)

The university engineers had the above points in mind in designing the ventilating systems of the Wisconsin High School, and the tests herein described were undertaken in order to ascertain the advisability of installing similar systems in the future buildings of the University.

The system was designed by J. M. Smith, operating engineer of the University heating station, under the supervision of Prof. H. J. Thorkelson, Consulting Engineer for the University.

The tests were undertaken especially with a view of throwing light upon the following questions:

1. What constitutes good ventilation?

2. Is proper ventilation a problem of supplying large volumes or merely a question of higher velocities with properly regulated humidity and temperatures?

3. Does recirculation give efficient as well as economical ventilation?

4. What is the effect of the washer upon the bacteria and carbon dioxide content of the air?

The writer desires to express his thanks to Prof. H. J. Thorkelson for his valuable advice and encouragement and to Prof. Wm. Black for his advice and assistance at various times. He is also indebted to Mr. J. M. Smith, operating engineer, and to Messrs. Bauer and Blanding, of the senior class in Mechanical Engineering, for valuable assistance rendered in preparing for and conduct-

ing the tests. The writer desires especially to express his thanks to Mr. E. J. Tully, Chemist, State Laboratory of Hygiene, for his hearty co-operation and valuable assistance in conducting the bacteria tests.

## DESCRIPTION OF BUILDING AND EQUIPMENT

In preparation for the tests herein recorded some preliminary tests were made on a small air washer and recirculating system which was built for experimental purposes and installed in one of the rooms in the Engineering Building. With this apparatus it was almost impossible to duplicate conditions as found in practice and as the tests were of a preliminary nature only, their results will not be recorded in this treatise.

The tests which will be described here were made at the University of Wisconsin High School. This is the newest of the buildings on the Wisconsin Campus, being used for the first time at the beginning of the present school year. Fig. 1 shows a view of this building. It is substantially built of Bedford stone and pressed brick, and equipped with steel window frames and sash. Each window has at least one venting panel and the windows in the first, second and third stories have two such panels.

These panels are designed with double contacts to insure closing exactly to prevent the passage of air. Only the south and middle portions of the building have been constructed, the north wall being left in a condition to facilitate future extension.

## SYSTEM OF HEATING

The building is heated with 8,530 square feet of direct radiation with the addition of 516 square feet of indirect radiation placed between the washer and the fan. The system is of the one pipe, direct steam type throughout. The direct radiators are of the Peerless pattern and they are supported on the walls by iron brackets. The indirect radiators are of the Vento cast iron type. This indirect radiation consists of four radiators set two radiators high and two wide and valved with hand valves in such a manner that one, two, three or all the radiators may be used as needed. The radiators are placed at such a height that ample space is left beneath them for by-passing the air to the fan.

All of the radiators in the building, including the indirect coils and by-pass damper, are controlled by the National automatic temperature control system. All air controlled valves on radia-

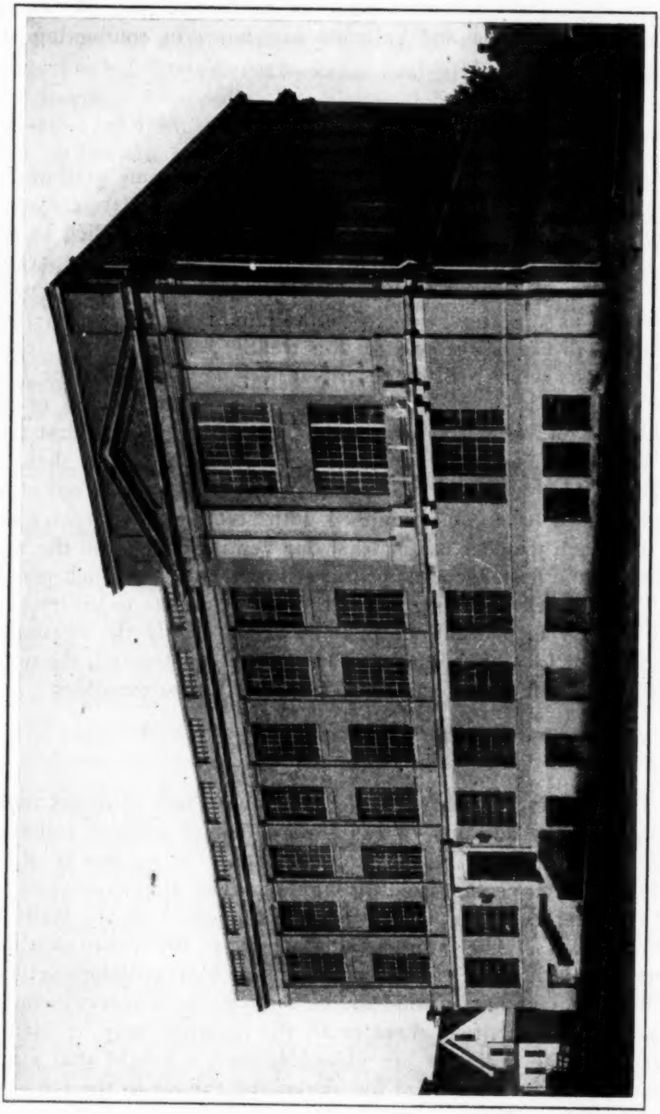


FIG. 1. THE NEW UNIVERSITY OF WISCONSIN HIGH SCHOOL BUILDING

tors are equipped with hand screw and lock shield stems for permitting the valves to be closed by hand, so that in mild weather any of these radiators may be cut out.

Steam is delivered to the building through a tunnel from the University heating plant.

## SYSTEM OF VENTILATION

The ventilation of the building consists of a blast fan discharging through ducts on the ceiling of the basement and rising to the rooms to be ventilated, entering the rooms near the ceiling. The vent ducts leave the rooms near the floor and are carried down to a system of tunnels below the basement floor which carry the air back to the fan through an air washer and indirect radiators. A sliding adjustable door is provided in the housing ahead of the air washer for the admission of outside air when necessary.

The toilet rooms are ventilated by a system of exhaust ventilation consisting of an exhaust fan in the attic and a system of ducts leading from the toilet rooms to the fan with a connection to each closet fixture.

The ventilation of the Chemical Laboratory consists of an exhaust fan in the attic with a duct leading to the Chemical Laboratory on the third floor. This duct has a register at both the floor and the ceiling. The exhaust fans discharge through Globe vents on the roof.

The general ventilation of the building is furnished by a No. 13 multivane blast fan rated at 165 R. P. M. direct connected to a 10 H. P. 500 volt direct current motor. The fan is rated to deliver 32,400 cubic feet per minute against a pressure of ¾ of an inch of water. The speed of the motor can be varied by field control.

The air washer is a Thomas "Acme" type. This washer consists of a spray chamber equipped with sufficient spray nozzles of approved type, a settling tank supplied with a float valve connected to the University water main to maintain the water level, and also an overflow and drain pipe connected to the sewer. It is equipped with a centrifugal pump which takes its suction from the settling tank and discharges through a basket strainer, to the spray nozzles. The eliminators are of the vertical type. The pump is direct connected to a 500 volt direct connected motor.

The entire system is designed with the view of future enlargement of the building and the capacity of the apparatus is sufficient to supply the entire building when completed. The ducts and tunnels are arranged so that the future wing of the building can be connected directly to the present system.

## DESCRIPTION OF THE APPARATUS AND METHODS USED

### *Steam and Power Consumption Tests*

The condensed steam from the building was taken directly from the steam traps and weighed. The condensate from the traps was at a temperature of about 210 degrees and it became

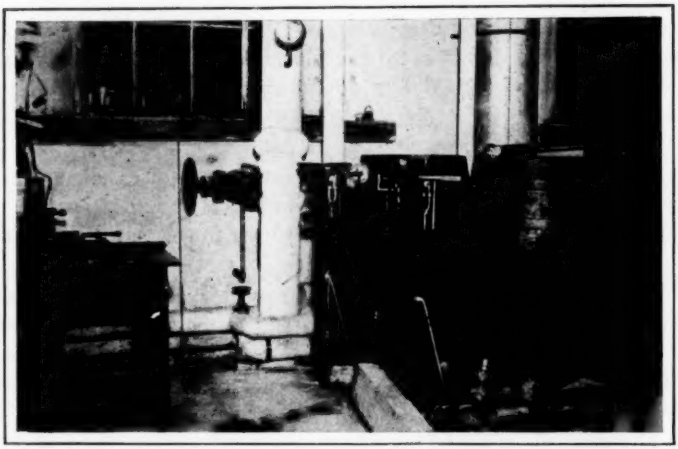


FIG. 2. THE ARRANGEMENT OF BARRELS AND SCALES USED IN THE TESTS

necessary to run it through a condenser barrel to prevent loss from evaporation. Fig. 2 is a view of the arrangement of barrels and scales used. Fig. 3 is the same view with the barrels and scales removed to show the condenser barrel and the steam traps. This view also shows the main steam line entering the building from the tunnel and the return piping. Calibrated meters of a standard make were used to measure the power consumption of the fan and washer motors.

No particular difficulty was experienced in weighing the condensate except that it was impossible to get a steady and uniform flow. This was undoubtedly due to the intermittent action of the thermostats and possibly, in some degree, to sticking of the steam traps.

AIR MEASURING APPARATUS

An anemometer was used to measure the air velocities. Since these instruments are often very unreliable great care was taken to calibrate it properly. A special apparatus was built for performing this calibration. It consists of a stand with a movable arm of such a radius that the anemometer moves around a circle twenty feet in circumference with one revolution of the arm. By means of a belt and pulleys any speed desired can be obtained. A lever arm on top of the stand is for starting and stopping the recording mechanism of the anemometer when the movable arm which carries the anemometer is in motion.

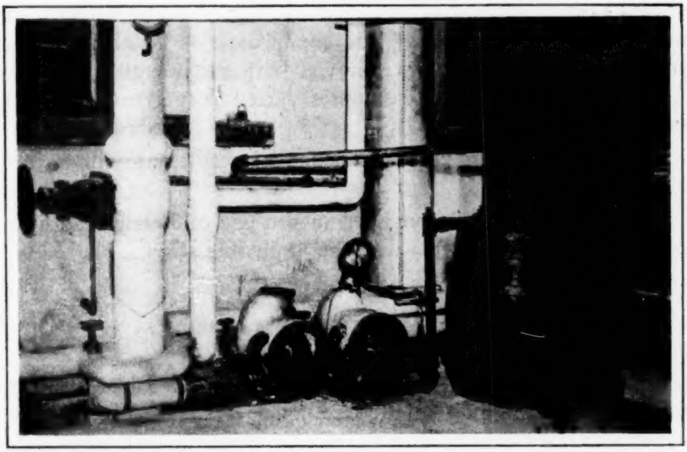


FIG. 3. VIEW OF THE CONDENSER BARREL AND THE STEAM TRAPS

Considerable difficulty was met in getting the true volume of the air entering the rooms. This will be explained later.

CARBON DIOXIDE APPARATUS

Haldane's portable apparatus was used to measure the carbon dioxide contained in the air. This apparatus is easily operated, and, while it is not the most accurate one on the market for measuring small amounts of carbon dioxide, it is accurate enough for most conditions met with in practice.

Haldane, in his book, "Methods of Air Analysis," states that his portable carbon dioxide apparatus will not vary more than one-half of one part in ten thousand either side of the correct

result. The writer checked the apparatus at various times by measuring the carbon dioxide contained in the outside air, and at no time did the readings vary more than the above mentioned amount. It is safe to say that even with a little practice, readings can be obtained which will not vary more than one part in ten thousand either side of the correct result.

### APPARATUS FOR BACTERIA TESTS

Two different methods were used to obtain a count of the number of bacteria in the air. The first consisted of drawing a measured amount of air through a sugar or sand filter. No consistent results were obtained from the use of sugar filters. The moisture in the air caused the sugar to stick to the inside of the filter tubes and it was removed with considerable difficulty. The time required to take samples varied very greatly with the sugar filters.

The sand filters gave very consistent results as will be seen later.

The second method consisted in the use of Petrie dishes and most of the bacteria tests were made in this way.

### APPARATUS FOR TRACING AIR CURRENTS

Several methods were used for tracing the air currents in the rooms. The common method of using ammonia and tumeric paper was tried but the change in color of the tumeric paper from yellow to pink was so gradual that it was next to impossible to tell when the action commenced. Both of the other methods used were quite successful.

Instead of using ammonia and tumeric paper, hydrogen sulphide and lead acetate were used. A rubber tube from the hydrogen sulphide generator was placed in the incoming duct and filter papers dipped in lead acetate were placed in various parts of the room. The filter papers turned black almost immediately upon coming in contact with the hydrogen sulphide gas. The odor of the hydrogen sulphide gas makes it inconvenient to use it, but on the whole it is fully as satisfactory as ammonia.

The air currents were also traced by using very light streamers of silk floss. This method proved very successful as very slight air currents can be traced in this way.

OBSERVATIONS

*Air Measurements*

As has been stated before, considerable difficulty was met with in getting the true volume of air entering the rooms.

Readings were taken at the ducts leading to the gymnasium. First a series of readings were taken at the register and then the register was removed and another set of readings taken holding the anemometer horizontally in the vertical duct leading to the room. The readings at the register showed an average of 482 feet per minute and those in the duct showed an average of 810 feet per minute.

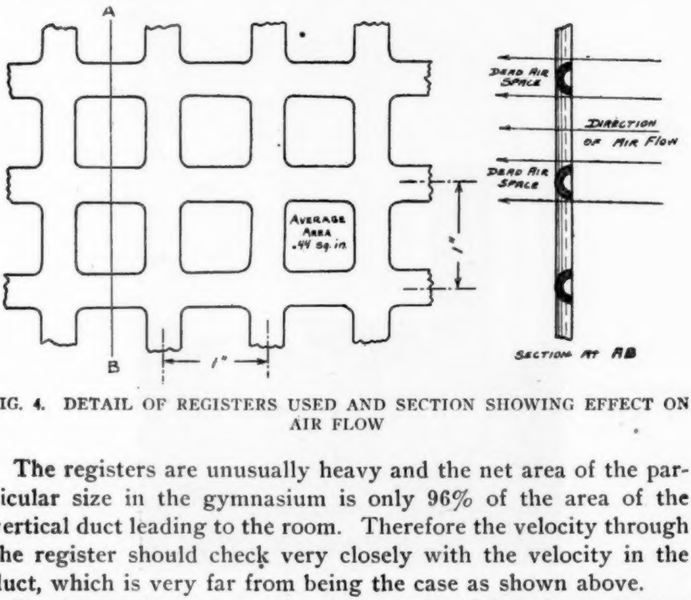



FIG. 4. DETAIL OF REGISTERS USED AND SECTION SHOWING EFFECT ON AIR FLOW

The registers are unusually heavy and the net area of the particular size in the gymnasium is only 96% of the area of the vertical duct leading to the room. Therefore the velocity through the register should check very closely with the velocity in the duct, which is very far from being the case as shown above.

Further readings were taken in a room which had a horizontal duct leading to it so that the anemometer could be left standing in the duct and readings taken after the register had been replaced.

In this room the velocity at the register was 386 ft. per minute; the velocity in the duct, with the register removed, was 944 ft. per minute; and the velocity in the duct after the register was replaced was 828 ft. per minute. In this room the net area of the register is 88% of the area of the duct leading to the room. Note that the ratio of velocities in the duct, with and without the

register in place, is 828/944 or 87.7%. As a check upon the above, readings of a similar nature were taken in another room. This room also had a horizontal duct leading to it so that the anemometer could be placed in the duct behind the register. Here the ratio of the velocities in the duct with and without the register in place was 86.8% and the ratio of the velocity at the register to that in the duct was only 35.7%. The net area of the register was 88% of the area of the duct.

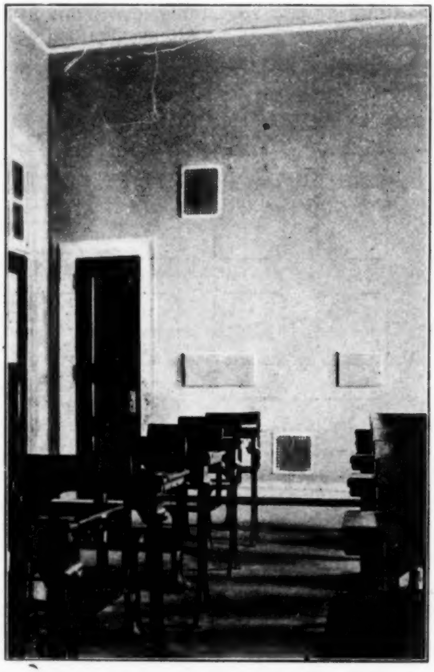


FIG. 5. REGISTER ARRANGEMENT IN ONE OF THE ROOMS

These tests show conclusively that the register deflected the air currents in such a manner as to give velocity values which were very much lower than the actual values, and that readings taken with the anemometer placed against the register are absolutely unreliable.

Fig. 4 is a sketch of a portion of one of the registers. They are made of pressed steel and the section at AB shows the form of the stampings.

The concave surface of the meshes will of course set up swirls in the air current but it would only be a guess to say what gen-

eral direction they would take. As in hydraulic work, there will probably be a contraction of the air current after it has passed between the meshes.

But in accounting for the low velocities obtained when the anemometer was held against the register face, it must be borne in mind that an anemometer is calibrated under conditions where

TABLE 1. RESULTS OF VELOCITY MEASUREMENTS IN ALL ROOMS

VENTILATION TEST

| Room Number | Size of Heat Duct Inches | Size of Heat Register In. | Net Area of Heat Duct. Sq. Ft. | Net Area of Heat Register. Sq. Ft. | Velocity of Air Entering Room Ft. per Minute | Cubic Feet of Air Supplied to Room per Minute | Volume of Room in Cu Ft | Student Capacity of Room | Cubic Feet of Space per Student | Cubic Feet of Air Supplied per Student per Minute | Time in Minutes Req'd to Change Air in Room | Relative Humidity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 4×4 | 4×8 | 0.111 | 0.098 | 652 | 65 | 2012 | | | | 31 | |
| 6 | 4×4 | 4×8 | 0.111 | 0.098 | 652 | 65 | 2012 | | | | 31 | |
| 8 | 8×12 | 16×12 | 0.666 | 0.587 | 869 | 510 | 16450 | 20 | 822 | 25.5 | 32 | 48 |
| 10 | 6×12 | 12×12 | 0.5 | 0.44 | 851 | 375 | 13600 | 28 | 486 | 13.4 | 36 | 31 |
| 15 | Two 12×32 | Two 24×32 | 2.66 2.66 | 2.51 2.51 | 765 712 | 3710 | 82280 | | | | 22 | 55 |
| 106 | 9×12 | 12×18 | 0.75 | 0.666 | 740 | 493 | 9880 | 26 | 380 | 19.0 | 20 | 51 |
| 107 | 8×12 | 12×16 | 0.666 | 0.587 | 759 | 445 | 8780 | 26 | 338 | 17.1 | 20 | 40 |
| 108 | 12×16 | 16×24 | 1.33 | 1.25 | 592 | 740 | 16600 | 127 | 130 | 5.8 | 22 | 48 |
| 109 | 8×12 | 12×16 | 0.666 | 0.587 | 814 | 478 | 9450 | 26 | 364 | 18.3 | 20 | 43 |
| 115 | 8×12 | 12×16 | 0.666 | 0.587 | 676 | 397 | 8300 | 31 | 268 | 12.8 | 21 | 42 |
| 207 | 9×12 | 12×18 | 0.75 | 0.666 | 535 | 356 | 9800 | 31 | 316 | 11.5 | 27 | 42 |
| 208 | 8×12 | 12×16 | 0.666 | 0.587 | 553 | 325 | 8780 | 26 | 338 | 12.5 | 27 | 38 |
| 209 | 12×16 | 16×24 | 1.33 | 1.25 | 918 | 1147 | 16600 | 127 | 130 | 9 | 14 | 47 |
| 210 | 8×12 | 12×16 | 0.666 | 0.587 | 614 | 360 | 9300 | 26 | 358 | 13.8 | 26 | 49 |
| 211 | 8×12 | 12×16 | 0.666 | 0.587 | 455 | 267 | 8450 | 31 | 273 | 8.6 | 32 | 47 |
| 212 | 6×7 | 7×12 | 0.291 | 0.257 | 477 | 123 | 3650 | 6 | 620 | 21.0 | 30 | 44 |
| 213 | 8×12 | 12×16 | 0.666 | 0.587 | 480 | 282 | 8450 | 20 | 425 | 14.1 | 30 | 41 |
| 214 | Two 12×35 | Two 24×35 | 2.91 2.91 | 2.74 2.74 | 367 896 | 3455 | 79760 | 361 | 120 | 9.6 | 23 | 55 |
| 308 | 10×12 | 12×20 | 0.833 | 0.733 | 510 | 374 | 10900 | 41 | 266 | 9.1 | 29 | 38 |
| 309 | 10×12 | 12×20 | 0.833 | 0.733 | 680 | 498 | 10900 | 25 | 437 | 20.0 | 22 | 40 |
| 310 | 6×6 | 6×12 | 0.25 | 0.22 | 245 | 54 | 3580 | | | | 66 | |
| 311 | 8×12 | 12×16 | 0.666 | 0.587 | 429 | 252 | 8650 | 15 | 279 | 16.8 | 34 | 42 |
| 312 | 8×12 | 12×16 | 0.666 | 0.587 | 139 | 82 | 8450 | 14 | 563 | 5.8 | 103 | 30 |
| 313 | 6×7 | 7×12 | 0.291 | 0.257 | 609 | 156 | 3650 | | | | 23 | |
| 314 | 8×12 | 12×16 | 0.666 | 0.587 | 395 | 232 | 8450 | 29 | 428 | 8.0 | 36 | 46 |
| Totals & Averages | | | Δ25.84 | Δ23.16 | *607 | Δ15241 | Δ168484 | | *367 | *13.6 | *26 | *44 |

Rooms No. 5, 6, 310, 313 are store rooms.
*Obtained by neglecting store rooms and room 312.

the air strikes with equal intensity over the entire surface of the vanes.

In a register such as the above, 56% of the face is composed of the meshes.

These meshes create a great number of dead air spaces, and, while the velocity through the meshes may be the same as the velocity in the riser, the anemometer will not show it because the

## STEAM AND TEMPERATURE LOGS

### TABLE II

FROM 7 A.M. FEB. 2 TO 7 A.M. FEB. 3, 1918

| Time | Weight of Steam from Radiators per Hr | Weight of Steam from Plenum Coils per Hour | Total Weight of Steam per Hour | Total Steam Consumption | Average Outside Temperature | Average Inside Temperature | Temperature Difference | Pounds of Steam per Hour per Degree Difference |
|---|---|---|---|---|---|---|---|---|
| 7:00 | | | | | | | | |
| 8:00 (7:30 A.M. Fan started) | 1063 | 12.0 | 1075 | 1075 | 22.1 | 69.1 | 47.0 | 22.6 |
| 9:00 | 1034 | 12.0 | 1046 | 2121 | 22.2 | 68.2 | 46.0 | 22.5 |
| 10:00 | 849.5 | 9.5 | 859 | 2980 | 23.8 | 68 | 44.2 | 19.2 |
| 11:00 | 772.5 | 9.5 | 782 | 3762 | 25.6 | 68.7 | 43.1 | 17.9 |
| 12:00 | 808.5 | 10.0 | 818.5 | 4580 | 26.8 | 68.7 | 41.9 | 19.3 |
| 1:00 | 766.5 | 11.0 | 777.5 | 5358 | 27.0 | 67.7 | 40.7 | 18.8 |
| 2:00 | 784.0 | 11.0 | 795 | 6153 | 27.6 | 67.4 | 39.8 | 19.7 |
| 3:00 | 767 | 11.0 | 778 | 6931 | 27.9 | 67.8 | 39.9 | 19.2 |
| 4:00 (3:30 P.M. Fan stopped) | 754 | 13.0 | 767 | 7698 | 28.1 | 67.9 | 39.8 | 19.0 |
| 5:00 | 891 | 11.0 | 902 | 8600 | 27.5 | 67.4 | 39.1 | 22.8 |
| 6:00 | 889 | 10.0 | 899 | 9499 | 26.8 | 66.9 | 40.1 | 22.2 |
| 7:00 | 932 | 10.5 | 942.5 | 10441 | 26.5 | 66.2 | 39.7 | 23.5 |
| 8:00 | 1147 | 11.5 | 1158.5 | 11600 | 26.1 | 65.9 | 39.8 | 28.8 |
| 9:00 | 1105 | 10.0 | 1115 | 12715 | 26.4 | 66.3 | 39.9 | 27.7 |
| 10:00 | 1170 | 11.0 | 1181 | 13896 | 26.2 | 66.4 | 40.2 | 29.1 |
| 11:00 | 1137 | 11.0 | 1148 | 15044 | 25.9 | 66.1 | 40.2 | 28.8 |
| 12:00 | 944 | 11.5 | 955 | 15999 | 26.0 | 66.1 | 40.1 | 23.6 |
| 1:00 | 1153.5 | 10.5 | 1164 | 17163 | 26.4 | 66.1 | 39.7 | 29.0 |
| 2:00 | 935.5 | 11.0 | 946.5 | 18109 | 26.5 | 66.5 | 40.0 | 23.4 |
| 3:00 | 937 | 10.0 | 947 | 19056 | 27.5 | 66.5 | 39.0 | 24.0 |
| 4:00 | 895 | 11.0 | 906 | 19962 | 28.0 | 66.1 | 38.1 | 23.5 |
| 5:00 | 977 | 11.0 | 988 | 20950 | 28.7 | 66.0 | 37.3 | 26.2 |
| 6:00 | 1084 | 11.0 | 1095 | 22045 | 29.3 | 65.8 | 36.5 | 29.7 |
| 7:00 | 1365.7 | 11.0 | 1376.7 | 23422 | 29.6 | 65.7 | 36.1 | 37.8 |
| Total | 23161 | 261 | 23422 | Ave. | 26.6 | 67.1 | 40.6 | 24.1 |

### TABLE III

FROM 7 P.M. FEB. 27 TO 7 A.M. FEB. 28, 1918

| Time | Weight of Steam from Radiators per Hour | Weight of Steam from Plenum Coils per Hour | Total Weight of Steam per Hour | Total Steam Consumption | Average Outside Temperature | Average Inside Temperature | Temperature Difference | Pounds of Steam per Hour per Degree Difference |
|---|---|---|---|---|---|---|---|---|
| 7:00 | | | | | | | | |
| 8:00 | 713 | 10 | 723 | 723 | 23.0 | 66.6 | 43.6 | 16.5 |
| 9:00 | 740 | 10 | 750 | 1473 | 22.2 | 66.2 | 44.0 | 16.8 |
| 10:00 | 856 | 11 | 867 | 2340 | 21.7 | 66.3 | 44.6 | 19.2 |
| 11:00 | 922 | 10 | 932 | 3272 | 21.3 | 66.5 | 45.2 | 20.4 |
| 12:00 | 848 | 10 | 858 | 4130 | 20.7 | 66.8 | 46.1 | 18.4 |
| 1:00 | 816 | 11 | 827 | 4957 | 20.1 | 66.3 | 46.2 | 17.7 |
| 2:00 | 725 | 11 | 736 | 5693 | 19.3 | 65.8 | 46.5 | 15.6 |
| 3:00 | 775 | 10 | 785 | 6478 | 18.9 | 65.9 | 47.0 | 16.5 |
| 4:00 | 975 | 10 | 985 | 7463 | 18.3 | 66.3 | 48 | 20.5 |
| 5:00 | 797 | 11 | 808 | 8271 | 17.9 | 66.8 | 48.4 | 16.4 |
| 6:00 | 1316 | 11 | 1327 | 9598 | 18.0 | 66 | 48 | 27.4 |
| 7:00 | 806 | 10 | 816 | 10414 | 19.3 | 66 | 46.7 | 17.2 |
| 8:00 (7:30 A.M. Fan started) | 810 | 11 | 821 | 11235 | 21.4 | 66.6 | 45.2 | 17.9 |
| 9:00 | 644 | 14 | 658 | 11893 | 24.2 | 66.6 | 42.4 | 15.2 |
| 10:00 | 663 | 14 | 677 | 12570 | 27.5 | 66.7 | 39.2 | 16.9 |
| 11:00 | 600 | 11 | 611 | 13181 | 30.3 | 67 | 36.7 | 16.3 |
| 12:00 | 500 | 10 | 510 | 13691 | 32.2 | 67.2 | 35 | 14.8 |
| 1:00 | 541 | 13 | 554 | 14245 | 34.2 | 67.3 | 33.1 | 16.4 |
| 2:00 | 490 | 14 | 504 | 14749 | 37.0 | 67.8 | 30.8 | 15.9 |
| 3:00 | 477 | 10 | 487 | 15236 | 39.3 | 68.2 | 28.9 | 16.5 |
| 4:00 (3:30 P.M. Fan stopped) | 516 | 11 | 527 | 15763 | 39.4 | 68.6 | 29.2 | 17.7 |
| 5:00 | 447 | 13 | 460 | 16223 | 37.1 | 68.8 | 31.7 | 14.7 |
| 6:00 | 429 | 10 | 439 | 16662 | 33 | 67.7 | 34.7 | 12.4 |
| 7:00 | 582 | 11 | 593 | 17225 | 30.2 | 67 | 36.8 | 15.8 |
| Total | 16958 | 267 | 17225 | Ave. | 26.0 | 66.8 | 40.8 | 17.2 |

### TABLE IV

FROM 8:15 P.M. MARCH 3 TO 11:15 MARCH 4, 1918

| Time | Weight of Steam from Radiators per Hour | Weight of Steam from Plenum Coils per Hour | Total Weight of Steam per Hour | Total Steam Consumption | Average Outside Temp. | Average Inside Temperature | Temperature Difference | Pounds of Steam per Hour per Degree Diff. |
|---|---|---|---|---|---|---|---|---|
| 8:15 | | | | | | | | |
| 9:15 | 756 | 10.5 | 766.5 | 766.5 | 24.5 | 64.7 | 40.2 | 18.8 |
| 10:15 | 861 | 10.5 | 871.5 | 1738 | 24.1 | 64.8 | 40.7 | 23.6 |
| 11:15 | 852 | 9 | 861 | 2599 | 24 | 64.9 | 40.9 | 20.8 |
| 12:15 (12:04 P.M. Fan started) | 975 | 10 | 985 | 3584 | 28.9 | 64.9 | 41 | 23.8 |
| 1:15 | 1041 | 10 | 1081 | 4655 | 23.7 | 65.2 | 41.5 | 25.1 |
| 2:15 | 842 | 11 | 853 | 5488 | 23.6 | 63.7 | 42.1 | 20 |
| 3:15 | 817 | 11 | 828 | 6316 | 23.7 | 65.8 | 42.1 | 19.4 |
| 4:15 | 797 | 12 | 809 | 7125 | 24.1 | 65.5 | 41.4 | 19.2 |
| 5:15 | 849 | 11 | 860 | 7985 | 24.1 | 65.4 | 41.3 | 20.5 |
| 6:15 | 838 | 10 | 848 | 8833 | 24.1 | 65.2 | 41 | 20.4 |
| 7:15 | 905 | 11 | 916 | 9749 | 24.9 | 65.3 | 40.4 | 22.4 |
| 8:15 | 815 | 11 | 826 | 10575 | 25.4 | 65.5 | 40.1 | 20.5 |
| 9:15 | 957 | 10 | 967 | 11542 | 26 | 65.8 | 39.8 | 24 |
| 10:15 | 871 | 11 | 881 | 12423 | 26.9 | 66.2 | 39.3 | 22.1 |
| 11:15 | 721 | 11 | 732 | 13155 | 27.8 | 66.1 | 38.3 | 18.8 |
| 12:15 | 743 | 12 | 755 | 13910 | 30.8 | 65.9 | 35.4 | 21.0 |
| 1:15 | 714 | 10 | 724 | 14634 | 31.4 | 65.3 | 33.9 | 21.0 |
| 2:15 | 818 | 10 | 828 | 15462 | 31.8 | 65.6 | 33.8 | 24.2 |
| 3:15 | 713 | 11 | 724 | 16186 | 31.6 | 66.1 | 34.5 | 20.7 |
| 4:15 | 776 | 11 | 787 | 16973 | 30.5 | 65.7 | 35.2 | 22.0 |
| 5:15 | 773 | 11 | 784 | 17757 | 29.6 | 64.9 | 35.3 | 21.9 |
| 6:15 | 779 | 10 | 789 | 18546 | 29 | 64.8 | 35.8 | 21.6 |
| 7:15 | 811 | 10 | 821 | 19367 | 29 | 66.1 | 36.1 | 22.2 |
| 8:15 (8:00 P.M. Fan stopped) | 763 | 10 | 773 | 20140 | 28.9 | 65.2 | 36.3 | 21.0 |
| 9:15 | 888 | 11 | 899 | 21039 | 29 | 64.6 | 35.6 | 25.0 |
| 10:15 | 1020 | 12 | 1032 | 22071 | 28.7 | 64.5 | 35.8 | 28.5 |
| 11:15 | 1059 | 12 | 1071 | 23143 | 28.8 | 64.9 | 36.6 | 29.0 |
| Total | 22864 | 289 | 23143 | Ave. | 27.0 | 65.3 | 38.3 | 22.1 |

vane area affected is much less than the vane area affected under calibrating conditions.

Velocity measurements were taken in all rooms. The results are tabulated in Table I. The registers were removed in each case and enough readings taken in the duct to give a fair average. The volumes were obtained by multiplying this average velocity by the net area of the register. That this method gives a fair value was shown later by velocity measurements taken at the suction side of the fan and in the two return tunnels from the rooms. Referring to Table I, it will be seen that the total volume supplied to all the rooms was 15,241 cubic feet per minute. The readings taken at the suction side of the fan gave a volume of 15,000 cubic feet per minute and the readings in the return tunnels gave a volume of 14,120 cubic feet per minute.

Table I shows that the velocity of the air entering the rooms ranged from 139 to 918 feet per minute with an average of 607 feet per minute. This average is about double the velocity usually recommended and in the opinion of the writer it is one of the desirable features of the system.

The volume of air supplied per student is low compared with the amount that would have to be supplied on the old basis of keeping the carbon dioxide content down to six parts in ten thousand. The cubic feet of air per student varies from 5.8 to 25.5 with an average of 13.6.

This seems low to one accustomed to the old figure of 30 cubic feet of air per student per minute but the air in the rooms always seemed fresh and clean and the amount supplied was apparently ample. (See questionaire submitted to the teachers in the building.)

### STEAM CONSUMPTION TESTS

Three steam consumption tests were made, of 24, 24 and 27 hours' duration, respectively.

The condensed steam was weighed every fifteen minutes and all temperature readings were taken every half hour. Power readings and humidity readings were also taken every half hour. The summarized steam weights and temperatures are given in Tables II, III and IV. Figs. 6, 7 and 8 are graphical logs plotted from Tables II, III and IV. The vento heaters in the housing were not in use during any of the tests. There was no steam on them and the condensation weighed from them was only leakage through the valves.

Test No. 1 was started at 7:00 A. M., February 2nd, and continued to 7:00 A. M., February 3rd. February 2nd was dark and

TABLE II-A

FAN AND AIR WASHER LOG

FROM 7.30 A.M. TO 3.30 P.M. FEB. 2 1915 — TEST No. 1

| TIME | MOTOR LOGS | | | | FAN AND WASHER LOG | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FAN MOTOR | | | PUMP MOTOR | TEMPERATURES | | | | | | | | HUMIDITY | | |
| | | | | | BEFORE WASHING | | | | AFTER WASHING | | | | | BEFORE WASHING | | |
| | | | | | WET BULB | | DRY BULB | | | | | | | | | |
| | R. P. M. | VOLTS | AMPERES | AMPERES | NORTH DUCT | SOUTH DUCT | NORTH DUCT | SOUTH DUCT | WET BULB | DRY BULB | FAN DELIVERY | WASHER WATER | NORTH DUCT | SOUTH DUCT | AFTER WASHING |
| 7:30 | 178 | 507 | 7.8 | 3.45 | | | | | | | | | | | |
| 8:00 | 177 | 532 | 8.0 | 3.95 | 56 | | 65.5 | | 57.5 | 60 | 60.5 | 56 | 55 | | 84 |
| 8:30 | 172 | 508 | 7.9 | 3.90 | 56.5 | | 65 | | 58 | 60 | 60.5 | 57 | 59 | | 89 |
| 9:00 | 178 | 530 | 8.0 | 4.25 | | | | | | | 60.5 | 58 | | | |
| 9:30 | 178 | 525 | 8.15 | 4.30 | 59 | 56.5 | 67 | 68 | 58 | 60 | 60.5 | 58 | 62 | 61 | 89 |
| 10:00 | 172 | 515 | 7.7 | 4.28 | 59 | 57.5 | 67 | 66 | 58.5 | 60 | 60 | 57 | 62 | 60 | 92 |
| 10:30 | 178 | 500 | 7.5 | 4.25 | 59 | 58 | 67.5 | 66.5 | 59 | 60.5 | 60 | 58 | 60 | 60 | 92 |
| 11:00 | 174 | 512 | 8.0 | 4.50 | 59 | 58 | 67.5 | 66.5 | 59 | 60.5 | 61.5 | 59 | 60 | 60 | 92 |
| 11:30 | 175 | 518 | 7.6 | 4.45 | 59 | 58 | 67 | 66.5 | 59 | 60.5 | 61.5 | 58 | 62 | 60 | 92 |
| 12:00 | 173 | 520 | 7.8 | 4.60 | 59 | 58.5 | 67 | 66.5 | 59.5 | 61.0 | 61.5 | 59 | 62 | 62 | 92 |
| 12:30 | 178 | 500 | 8.0 | 4.50 | 59 | 58.5 | 67 | 66.5 | 59 | 60.5 | 61.5 | 59 | 62 | 60 | 92 |
| 1:00 | 171 | 515 | 7.5 | 4.50 | 58.5 | 58 | 66.5 | 66.5 | 59 | 60.5 | 61.5 | 59 | 62 | 62 | 92 |
| 1:30 | 172 | 520 | 8.0 | 4.50 | 59.5 | 58 | 67.5 | 66.5 | 58.5 | 60 | 61.5 | 58 | 62 | 62 | 92 |
| 2:00 | 174 | 530 | 8.0 | 4.55 | 59.5 | 58.5 | 67 | 66 | 58.5 | 59.5 | 61.5 | 58.5 | 64 | 65 | 94 |
| 2:30 | 172 | 520 | 7.5 | 4.45 | 58 | 59 | 66 | 67 | 59 | 60 | 61.5 | 58 | 62 | 62 | 94 |
| 3:00 | 174 | 510 | 8.0 | 4.55 | 58.5 | 59 | 66 | 66.5 | 59 | 60 | 61.5 | 57 | 64 | 64 | 94 |
| 3:30 | 174 | 512 | 8.0 | 4.55 | 58 | 59 | 66 | 67 | 60 | 61 | 61.5 | 59 | 64 | 64 | 94 |
| AVE. | 173 | 516 | 7.85 | 4.33 | 58.5 | 58.2 | 66.6 | 66.6 | 58.7 | 60.5 | 60.9 | 58.0 | 61.5 | 61.7 | 91.6 |

OUTSIDE HUMIDITY AT 7 A.M. FEB. 3 WAS 97% AND WAS 98% AT 7 A.M. FEB. 4 AND REMAINED PRACTICALLY CONSTANT DURING THE 24 HOURS. THE BAROMETER READ 29.0 IN. AT 7 A.M. FEB. 3 AND DROPPED GRADUALLY TO 28.75 IN. AT 7 A.M. FEB. 4

TABLE III-A.

FAN AND AIR WASHER LOG

FROM 7.30 A.M. TO 3.30 P.M. FEB. 28, 1915 — TEST No. 2.

| TIME | MOTOR LOGS | | | | FAN AND WASHER LOG | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FAN MOTOR | | | PUMP MOTOR | TEMPERATURES | | | | | | HUMIDITY | |
| | | | | | BEFORE WASHING | | AFTER WASHING | | | | | |
| | R.P.M. | VOLTS | AMPERES | AMPERES | WET BULB | DRY BULB | WET BULB | DRY BULB | FAN DELIVERY | WASHER WATER | BEFORE WASHING | AFTER WASHING |
| 7:30 | 170 | 512 | 7.9 | 3.85 | 53 | 65 | 54 | 58 | 60 | 55 | 44 | 77 |
| 8:00 | 170 | 512 | 7.8 | 4.05 | 54 | 65 | 56 | 58 | 60 | 55 | 48 | 89 |
| 8:30 | 175 | 515 | 7.8 | 4.20 | | | | | | 56 | | |
| 9:00 | 175 | 515 | 8.2 | 4.35 | 56 | 66 | 58 | 59 | 60 | 57 | 57 | 94 |
| 9:30 | 172 | 507 | 7.7 | 4.50 | | | | | | | | |
| 10:00 | 174 | 525 | 8.0 | 4.65 | 57.5 | 65.5 | 59 | 60 | 60 | 59 | 62 | 94 |
| 10:30 | 173 | 525 | 8.0 | 4.65 | | | | | | | | |
| 11:00 | 175 | 525 | 8.1 | 4.75 | 58 | 65.8 | 60 | 60 | 60 | 58 | 64 | 100 |
| 11:30 | 174 | 510 | 7.9 | 4.70 | | | | | | | | |
| 12:00 | 173 | 505 | 7.9 | 4.65 | 58 | 66 | 59.7 | 60 | 60 | 58 | 62 | 98 |
| 12:30 | 173 | 510 | 8.1 | 4.75 | | | | | | | | |
| 1:00 | 174 | 520 | 8.0 | 4.80 | 58 | 66 | 59.7 | 60 | 60 | 58 | 62 | 98 |
| 1:30 | 175 | 525 | 8.0 | 4.75 | | | | | | | | |
| 2:00 | 174 | 525 | 8.2 | 5.00 | 58 | 66 | 59.5 | 60 | 60 | 59 | 62 | 97 |
| 2:30 | 176 | 525 | 8.5 | 5.20 | | | | | | | | |
| 3:00 | 175 | 520 | 8.2 | 5.00 | 58 | 66 | 59.5 | 60 | 60 | 59 | 62 | 97 |
| 3:30 | 176 | 525 | 8.2 | 5.00 | 58 | 66 | 60 | 60 | 60 | 59 | 62 | 100 |
| AVE. | 174 | 518 | 8.0 | 4.64 | 56.8 | 65.6 | 58.5 | 59.6 | 60 | 57.5 | 58.5 | 94.4 |

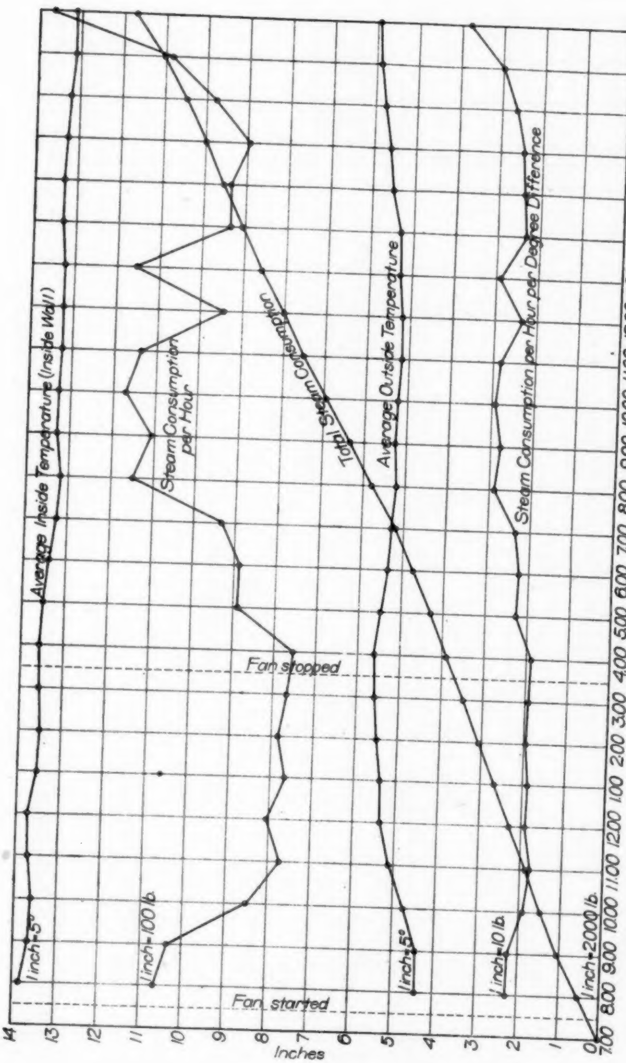



FIG. 6. GRAPHICAL LOG PLOTTED FROM TABLE 2

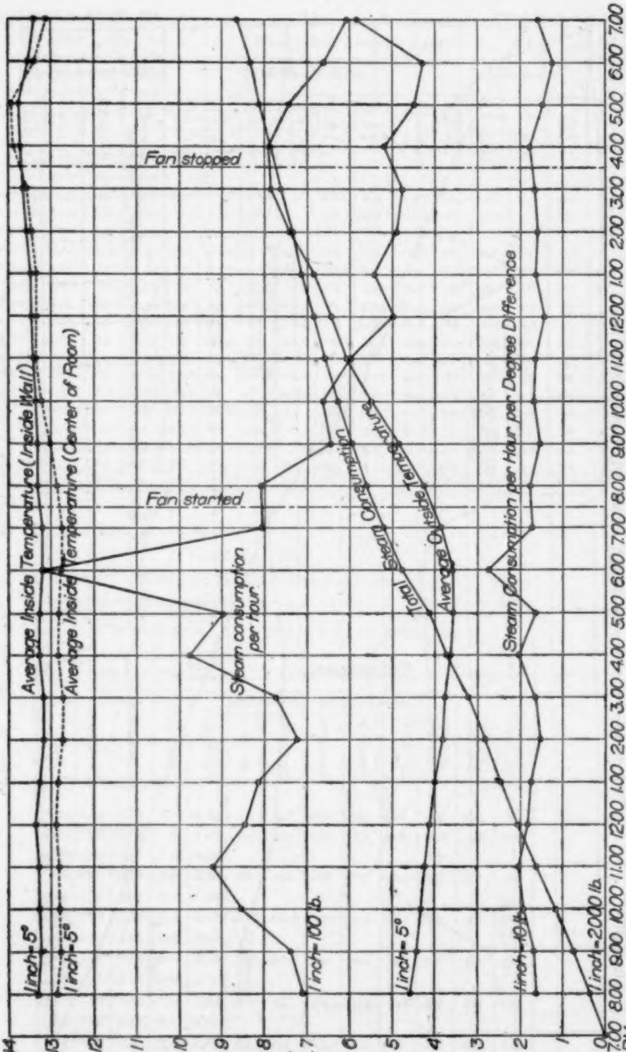



FIG. 7. GRAPHICAL LOG PLOTTED FROM TABLE 3

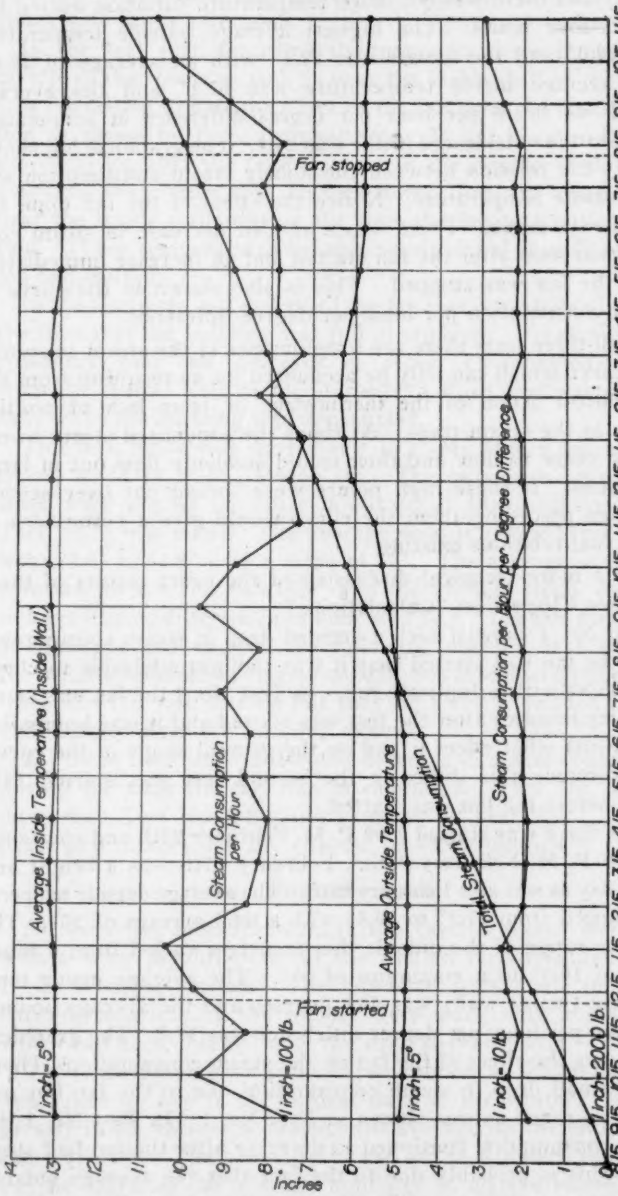



FIG. 8. GRAPHICAL LOG PLOTTED FROM TABLE 4

cloudy and there was not much temperature variation during the twenty-four hours. The highest average outside temperature was 29.6° and the lowest was 22.1° with an average of 26.6°. The average inside temperature was 67.1° and the average pounds of steam per hour per degree difference in temperature between the outside and inside was 24.1. The graphical log shows clearly the relation between the hourly steam consumption and the outside temperature. Notice the effect of the fan upon the steam rate curve. There was a sudden decrease in steam consumption soon after the fan started and an increase immediately after the fan was stopped. This is also shown in the curve of steam consumption per hour per degree difference.

In all three tests there are irregularities in the steam consumption curve which can only be accounted for as resulting from the intermittent action of the thermostats, or from lack of positive action in the steam traps. At times the condensed steam would almost cease to flow and then would suddenly flow out in large quantities. If these high points were spread out over several readings preceding them the curve would give a better idea of the actual relations existing.

For a more technical discussion of the exact results of these tests see Chapter on "Calculations."

Test No. 1 showed such a decided drop in steam consumption after the fan had started that it was thought advisable to check the results with a duplicate run. In Test No. 1 the fan was started thirty minutes after the test was started and it was impossible to tell just what effect it had on the general shape of the curve. To overcome this difficulty the second test was started 12½ hours before the fan was started.

Test No. 2 was started 7:00 P. M. February 27th and continued to 7:00 P. M. February 28th. February 27th was a bright and sunny day as was also February 28th. The average outside temperature ranged from 17.9° to 39.4° with a total average of 26°. The extreme range of the outside thermometers varied from a minimum of 16.5° to a maximum of 50°. The average inside temperature (inside wall) was 66.8 degrees and the average pounds of steam per hour per degree difference was 17.2. The graphical log shows the effect of the fan on the steam consumption. There was a small drop in steam consumption due to the fan but not nearly as much as was shown in Test No. 1. In Test No. 2 the steam consumption continued to decrease after the fan had stopped. This is probably due to the fact that the average outside temperature curve was still rising and that the walls must have

absorbed considerable heat from the high temperature on the sunny side in the afternoon.

In the test just described thermometers were hung in the middle of the rooms as well as near the inside wall of the rooms. It is interesting to note the effect of the fan upon the heat distribution as shown by these thermometers. It can be seen from the graphical log that the temperatures in the middle of the rooms averaged more than two degrees lower than the temperatures near the inside walls during the time the fan was not in operation. These temperatures became nearly equal shortly after the fan had started.

In the two tests just described the fan was operated only during the time that the building was full of students. To eliminate the possibility that the decrease in steam consumption resulted from the animal heat of the students, a third test was run at a time when the building was unoccupied.

This test, No. 3, was started at 8:15 P. M., March 3rd, and continued to 11:15 P. M., March 4th. The outside weather conditions were almost an exact duplicate of the conditions when Test No. 1 was made. The average outside temperature ranged from 23.6° to 31.8° with a mean of 27°. The average inside temperature for the run was 65.3° and the average steam consumption per degree difference per hour was 22.1. The fan was started at midnight and stopped the following evening at 8:15 P. M. No definite decrease in steam consumption is shown by the curves when the fan was started but they do show a decided increase immediately after the fan was stopped.

All three tests show a decided decrease in steam consumption during the time the fan was in operation. Test No. 3 shows more than Test No. 2 but not as much as Test No. 1. For the exact percentages see the chapter on "Calculations."

## HUMIDITY TESTS

All humidity measurements in the various rooms were made with a sling psychrometer of the pattern recommended by the U. S. Weather Bureau. The humidity tests made on the air entering and leaving the washer were made with a Hygrodeik which had been checked with the sling psychrometer.

The relative humidity in the various rooms as shown in Table I was taken on one of the coldest days in the winter. It varied greatly in the various rooms but the average for the entire building was 44%. The humidity of the air as it enters the washer can be taken as the average humidity of all the rooms. That

this assumption is correct is shown by the following measurements taken in some of the rooms on the day steam consumption Test No. 1 was made.

| Room Number | Wet Bulb | Dry Bulb | Humidity |
|---|---|---|---|
| Gymnasium .......... | 58.3 | 63.5 | 74 |
| Room No. 10......... | 54.5 | 65 | 50 |
| Room No. 108......... | 59 | 69 | 55 |
| Room No. 209......... | 59 | 65 | 70 |
| Assembly ............ | 61.7 | 69 | 66 |
| Room No. 309......... | 55.5 | 66 | 51 |
| Room No. 311......... | 57.5 | 64.5 | 66 |
| Room No. 211......... | 60 | 69 | 59 |
| Room No. 107......... | 58.5 | 67 | 60 |
| Average .............. | 28.2 | 66.4 | 61.2 |

The average humidity of all the above rooms was 61.2% as compared with 61.6% in the air entering the washer. In Test No. 2 the average humidity of the air entering the washer was 58.5%, and in Test No. 3 it was 61.5%. In each case the air had a relative humidity of about 95% as it left the washer.

There can be no doubt but that a reasonably high humidity has a very beneficial effect upon the quality of the air. It not only improves the quality of the air for breathing but it makes it possible to keep the rooms at a much lower temperature. An inspection of any of the temperature log sheets will show that the average temperature was rarely above 67°, and often it was below 65° in some of the rooms, without a single complaint being registered.

The temperature of the air leaving the washer was usually about 60°. A series of temperature measurements taken in the registers of the various rooms showed that the air entering the rooms was also 60°. At first glance one would say that this was too cold. As a matter of fact it proved to be a benefit rather than a detriment, as it seemed to give more life to the air in the rooms and at the same time did not cause any uncomfortable draughts as would be expected.

This test was made on March 30th, when the weather was quite mild. No test has been made during the summer so that the writer is unable to state what entering temperature might be expected if recirculation is resorted to during the summer months. However, in view of the fact that the air entered at 60° on a comparatively mild day, it is not likely that the temperature would reach an unreasonable value during the warmer months.

CARBON DIOXIDE TESTS

The following carbon dioxide tests were made on the two sides of the washer and in the various rooms mentioned.

Tests on air entering washer December 14th. 3:20 P. M.:

Sample No. 1 showed 11 parts carbon dioxide in 10,000.

Sample No. 2 showed 10 parts carbon dioxide in 10,000.

Tests on air leaving washer December 14th. 3:35 P. M.

Sample No. 1 showed 6 parts carbon dioxide in 10,000.

Sample No. 2 showed 6 parts carbon dioxide in 10,000.

The tests tabulated below were made December 16th.

TESTS ON AIR ENTERING THE WASHER

| Time | 10:45 | 10:55 | 11:04 | 2:45 | 2:56 | Average |
|---|---|---|---|---|---|---|
| Parts in 10,000 | 8 | 6 | 8 | 10 | 10 | 8.4 |

TESTS ON AIR LEAVING THE WASHER

| Time | 10:15 | 11:20 | 11:30 | 11:42 | 11:53 | 2:15 | 2:30 | Average |
|---|---|---|---|---|---|---|---|---|
| Parts in 10,000 | 10 | 9 | 7 | 8 | 9 | 8 | 6 | 8.14 |

On January 12th the following results were obtained:

Sample No. 1 taken 9:55 A. M. on the air after being washed showed 6 parts in 10,000.

Sample No. 2 taken 10:05 A. M. on the air after being washed showed 7 parts in 10,000.

Sample No. 3 taken 10:25 A. M. on the air before being washed showed 9 parts in 10,000.

Sample No. 4 taken 10:40 A. M. on the air before being washed showed 9 parts in 10,000.

Sample No. 5 taken 10:53 A. M. on the air before being washed showed 8 parts in 10,000.

An average of the above set of readings gives 6.5 parts in 10,000 after washing and 8.66 parts in 10,000 before washing.

The above tests lead to the conclusion that the washer water absorbs a part of the carbon dioxide brought from the rooms by the air. It is impossible to say just what this rate of absorption is as the results varied considerably and the readings were not taken on the two sides of the washer at exactly the same time. More work needs to be done along this line.

Tests were also made on the air in some of the rooms. In room No. 311 a sample was taken while the class was in the room and it contained 15 parts of carbon dioxide while a sample taken seven minutes after the class had left the room showed 13 parts of carbon dioxide in 10,000.

On February 26th samples were taken in room No. 211 while 19 students were in the room. The first sample showed 15 parts, the second 13 parts, and the third 13 parts of carbon dioxide in 10,000. These tests were made in the afternoon, the room having been in use all day.

On this same day samples were also taken in the auditorium near the close of an assembly period, and while there were 250 students in the room. The three samples taken showed 15, 20 and 17 parts of carbon dioxide, respectively.

The carbon dioxide content shown by the above tests is considerably higher than would be considered good practice according to the old standard of 6 parts in 10,000, but it is lower than would be expected in view of the fact that all the air is recirculated and none is taken from the outside except the usual unavoidable leakage. As far as could be detected the above amounts of carbon dioxide had no detrimental effect upon the quality of the air in the rooms. The air seemed fresh and clean and no odors were detected.

### THE AIR WASHER AS A DUST REMOVER

No actual dust counts were taken on the washer but it was readily seen that it was quite efficient in this respect. At the end of a week's run the washer water was found to be very dirty and considerable sediment was found on the bottom of the tank. However, the writer doubts very much the claims made by most washer manufacturers to the effect that their washers will remove 98% of the solid matter in the air.

### BACTERIA TESTS

These tests showed some startling and unexpected results. When using recirculated water the washer supplied bacteria to the air instead of removing them and even when using new water continuously it did not show any marked efficiency as a bacteria remover. These results are directly contrary to the results reported by G. C. Whipple and M. C. Whipple of Harvard. (See the American Journal of Public Health, 1913, Vol. 23, pp. 1138-1153.)

The tabulated results of the tests are given in the following tables: Table V shows the results obtained with the use of sand and sugar filters. No conclusive results were obtained using sugar filters, probably due to the trouble mentioned previously in the description of the apparatus. On an average, the sugar filters showed about the same number of bacteria on each side

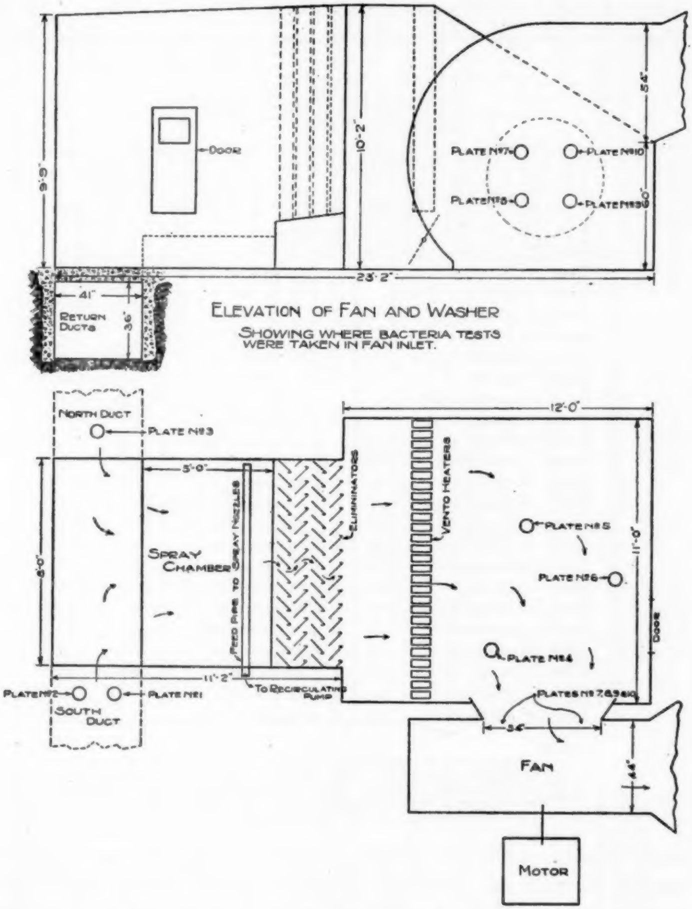



FIG. 9. PLAN OF FAN AND WASHER, SHOWING WHERE BACTERIA TESTS WERE TAKEN

of the washer but the highest number would appear on one side of the washer in one test and on the opposite side in the next.

The sand filters showed conclusively that the washer delivered bacteria to the air. The four sand filter tests checked each other very closely and showed an increase of bacteria in a ratio of about two to one. At the same time that the sand filter tests

TABLE V

BACTERIA TESTS ON AIR WASHER

ALL SAMPLES TAKEN WITH SUGAR FILTERS AND SAND FILTERS

| | Date of Test | Volume of Sample in Litres | Air Before Washing | | | | | | Air After Washing | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Time of Day | Time Required Minutes | Bacteria (Agar Count) | Bacteria (Gelatine Count) | Moulds | Total Bacteria and Moulds | Time of Day | Time Required Minutes | Bacteria (Agar Count) | Bacteria (Gelatine Count) | Moulds | Total Bacteria and Moulds |
| Sugar Filters Used | Jan. 5 | 5 | 3:00-3:10 | 10 | 42 | | | 42 | 2:40-2:50 | 10 | 4 | | | 4 |
| | Jan. 6 | 5 | 3:09-3:20 | 11 | 4 | | | 4 | 2:41-2:54 | 13 | 3 | | | 3 |
| | Jan. 7 | 5 | 2:40-2:53 | 13 | 1 | | | 1 | 3:00-3:05 | 8 | 0 | | | 0 |
| | Jan. 8 | 5 | 3:18-3:25 | 8 | 7 | | | 7 | 2:57-3:05 | 8 | 1 | | | 1 |
| | Jan. 11 | 10 | 2:30-3:06 | 36 | 4 | | | 4 | 3:14-3:30 | 16 | 0 | | | 0 |
| | Jan. 12 | 10 | 2:18-3:10 | 14 | 1 | | | 1 | 2:32-2:43 | 11 | 0 | | | 0 |
| | Jan. 13 | 10 | 2:35-2:53 | 18 | 0 | | | 0 | 3:04-3:15 | 11 | 0 | | | 0 |
| | Jan. 14 | 10 | 3:12-3:34 | 22 | 5 | | | 5 | 2:40-3:05 | 23 | 3 | | | 3 |
| | Jan. 15 | 10 | 2:06-2:44 | 38 | 0 | | | 0 | 2:52-3:37 | 46 | 3 | | | 3 |
| | Jan. 25 | 10 | 2:30-2:52 | 22 | | 25 | 2 | 27 | 2:30-2:52 | 22 | | 2 | 0 | 2 |
| | Jan. 26 | 10 | 2:48-3:11 | 23 | | 21 | 1 | 22 | 2:48-3:11 | 23 | | 11 | 0 | 11 |
| | Jan. 27 | 10 | 2:32-3:28 | 56 | | 12 | 11 | 23 | 2:32-3:23 | 51 | | 20 | 0 | 20 |
| | Jan. 28 | 10 | 2:29-3:19 | 50 | | 50 | 1 | 51 | 2:29-3:19 | 50 | | 20 | 0 | 20 |
| | Jan. 29 | 10 | 2:30-3:16 | 45 | | 25 | 4 | 29 | 2:30-3:15 | 45 | | 10 | 0 | 10 |
| | Feb. 1 | 10 | 2:43-3:19 | 36 | | 25 | 0 | 25 | 2:43-3:19 | 36 | | 39 | 0 | 39 |
| | Feb. 2 | 10 | 2:30-3:16 | 35 | | 10 | 0 | 10 | 2:30-3:05 | 35 | | 40 | 0 | 40 |
| | Feb. 3 | 10 | 1:34-2:25 | 31 | | 45 | 0 | 45 | 1:54-2:25 | 31 | | 198 | 2 | 200 |
| | Feb. 4 | 10 | 2:42-3:25 | 43 | | 6 | 2 | 8 | 2:42-3:25 | 43 | | 16 | 1 | 17 |
| Sand Filters Used | Feb. 8 | 10 | 3:00-3:25 | 25 | | 30 | 2 | 32 | 3:00-3:25 | 25 | | 70 | 4 | 74 |
| | Feb. 9 | 10 | 2:35-3:00 | 25 | | 33 | 0 | 33 | 2:35-3:00 | 25 | | 60 | 2 | 62 |
| | Feb. 10 | 10 | 2:55-3:20 | 25 | | 31 | 1 | 32 | 2:55-3:20 | 25 | | 57 | 2 | 59 |
| | Feb. 11 | 10 | 2:45-3:10 | 25 | | 36 | 0 | 36 | 2:45-3:10 | 25 | | 66 | 0 | 66 |

NOTE

THE SAMPLE OF THE AIR BEFORE WASHING ON JANUARY 5TH WAS TAKEN DIRECTLY IN FRONT OF THE WASHER AND EVIDENTLY WATER FROM THE WASHER SPLASHED INTO THE FILTER TUBE. ALL OTHER SAMPLES OF THE AIR BEFORE WASHING WERE TAKEN IN THE RETURN DUCTS WHERE IT WAS IMPOSSIBLE FOR THE WASHER WATER TO REACH THEM.

THE WASHER WATER WAS CHANGED WEEKLY.

were taken, a series of Petrie plates were exposed for the same length of time on each side of the washer. These also show conclusively that the number of bacteria in the air is increased by the washer, but at a very much higher ratio than shown by the sand filters. The results of the tests with Petrie dishes are tabulated in Table VI. Fig. 9 is a plan of the washer and fan housing showing where the bacteria plates were exposed. The writer is unable to state just why the plates should show such a greater ratio above that shown by the sand filters. It can not be

## TABLE VI

### BACTERIA TESTS ON AIR WASHER

CULTURES TAKEN ON PETRI DISHES

| | Date of Test | Time of Exposure Minutes | Air Before Washing | | | | | | | | Air After Washing | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Samples Taken in Return Ducts to Washer | | | | | | Average Bacteria per Plate | Average Moulds per Plate | Samples Taken in Plenum Chamber | | | | | | Samples Taken in Inlet to Fan | | | | | | | | Average Bacteria per Plate | Average Moulds per Plate |
| | | | Plate No. 1 | | Plate No. 2 | | Plate No. 3 | | | | Plate No. 4 | | Plate No. 5 | | Plate No. 6 | | Plate No. 7 | | Plate No. 8 | | Plate No. 9 | | Plate No. 10 | | | |
| | | | Bacteria | Moulds | Bacteria | Moulds | Bacteria | Moulds | | | Bacteria | Moulds | Bacteria | Moulds | Bacteria | Moulds | Bacteria | Moulds | Bacteria | Moulds | Bacteria | Moulds | Bacteria | Moulds | | |
| (a) | Feb 8 | 25 | 40 | 0 | 18 | 0 | 40 | 2 | 33 | 1 | 2400 | 0 | 2500 | 3 | 1600 | 0 | | | | | | | | | 2166 | 1 |
| (a) | Feb. 9 | 25 | 30 | 9 | 60 | 17 | 50 | 8 | 47 | 11 | 4000 | 4 | 2000 | 4 | 200 | 9 | | | | | | | | | 2400 | 6 |
| (a) | Feb. 10 | 25 | 70 | 2 | 90 | 9 | 30 | 5 | 63 | 5 | 4000 | 2 | 3600 | 7 | 3200 | 4 | | | | | | | | | 3600 | 4 |
| (a) | Feb 11 | 25 | 30 | 2 | 25 | 1 | 26 | 3 | 27 | 2 | 6000 | 2 | 4800 | 10 | 3200 | 10 | | | | | | | | | 4666 | 7 |
| (a) | Mar 3 | 30 | 58 | 18 | 69 | 18 | 26 | 9 | 47 | 15 | 6500 | 10 | 4000 | 10 | 1200 | 6 | | | | | | | | | 3500 | 9 |
| (a) | Mar 16 | 30 | 68 | 15 | 75 | 18 | 40 | 4 | 61 | 12 | 1000 | 9 | 1600 | 11 | | | 3500 | 8 | 4200 | 8 | 275 | 22 | 3000 | 20 | 2265 | 13 |
| (b) | Mar 25 | 30 | 35 | 18 | 40 | 38 | 20 | 9 | 32 | 22 | 50 | 11 | | | | | 14 | 20 | 80 | 27 | 14 | 15 | 12 | 24 | 34 | 19 |
| (b) | Apr. 1 | 30 | 40 | 30 | 36 | 19 | 12 | 13 | 29 | 21 | 60 | 10 | | | | | 45 | 18 | 35 | 27 | 7 | 24 | 8 | 30 | 30 | 20 |
| (c) | Apr. 16 | 30 | 50 | 36 | 30 | 39 | 22 | 16 | 34 | 30 | 3200 | 13 | | | | | 2000 | 2 | 4000 | 20 | 800 | 19 | 2000 | 20 | 2400 | 15 |
| (c) | Apr. 23 | 30 | 250 | 200 | 350 | 130 | 65 | 60 | 221 | 137 | 3200 | 30 | | | | | 730 | 70 | 1300 | 85 | 1100 | 90 | 3100 | 90 | 1886 | 23 |

(a) WASHER WATER CHANGED WEEKLY. (b) FRESH WATER USED CONTINUOUSLY. (c) WASHER WATER CHANGED DAILY.

## TABLE VII

### BACTERIA TEST ON WASHER WATER

| Date of Test | Time | Solids per Million | Turbidity | Bacteria (Gelatine Count) | Bacteria (Agar Count) |
|---|---|---|---|---|---|
| Dec. 7 | 8:00 AM | 180 | | 200 | 100 |
| Dec 7 | 3:30 PM | | Decided | 1200 | 250 |
| Dec. 8 | 3:30 PM | | Decided | 5000 | 2500 |
| Dec. 9 | 3:30 PM | 426 | 25 | 3000 | 4200 |
| Dec 10 | 3:30 PM | 482 | 30 | 2000 | 12000 |
| Dec 11 | 3:00 PM | 522 | 40 | 1500 | 30000 |

## TABLE VIII

### BACTERIA TEST ON AIR IN ROOMS

| Date of Test | Where Taken | Time of Exposure Minutes | Air Entering Room | | Air Leaving Room | | Air in Center of Room | |
|---|---|---|---|---|---|---|---|---|
| | | | Bacteria | Moulds | Bacteria | Moulds | Bacteria | Moulds |
| Feb 25 | Room No. 214 | 30 | 107 | 3 | 50 | 11 | | |
| Feb. 25 | Room No. 211 | 30 | 60 | 6 | 26 | 2 | 30 | 2 |
| Feb. 26 | Room No. 211 | 30 | 83 | 0 | 42 | 2 | 32 | 4 |

NOTE

ROOM No. 214 IS THE AUDITORIUM AND THERE WERE 250 STUDENTS IN THE ROOM AT THE TIME THE TEST WAS TAKEN

ROOM No. 211 IS A TYPICAL CLASS ROOM AND THERE WERE 20 STUDENTS IN THE ROOM DURING THE TESTS

## TABLE IX

### BACTERIA TESTS ON OUTDOOR AIR

| Date of Test | Where Taken | Time of Exposure Minutes | Plate No. 1 | | Plate No. 2 | | Average Bact. per Plate | Average Moulds per Plate |
|---|---|---|---|---|---|---|---|---|
| | | | Bacteria | Moulds | Bacteria | Moulds | | |
| Mar. 28 | (a) | 30 | 45 | 18 | 40 | 16 | 42 | 17 |
| Apr 1 | (b) | 30 | 13 | 7 | 15 | 10 | 14 | 8 |
| Apr. 16 | (c) | 30 | 31 | 45 | | | 31 | 45 |
| Apr. 23 | (d) | 30 | 290 | 160 | 350 | 130 | 320 | 145 |

(a) OUTSIDE OF BASEMENT WINDOW, 1 FT. FROM GROUND.
(b) OUTSIDE OF FIRST STORY WINDOW, 12 FT. FROM GROUND
(c) OUTSIDE OF BASEMENT WINDOW, 1 FT. FROM GROUND.
(d) OUTSIDE OF FIRST STORY WINDOW, 12 FT. FROM GROUND

wholly explained from the different air velocities on the two sides of the washer. The average velocity of the air entering the fan was 940 feet per minute. The average velocity on the other side of the washer was 564 feet per minute in the north duct and 813 feet per minute in the south duct, and it can be easily seen that this will not account for all of the difference.

The tests show no appreciable decrease in bacteria due to the washer water being changed each Monday. Evidently the wash-

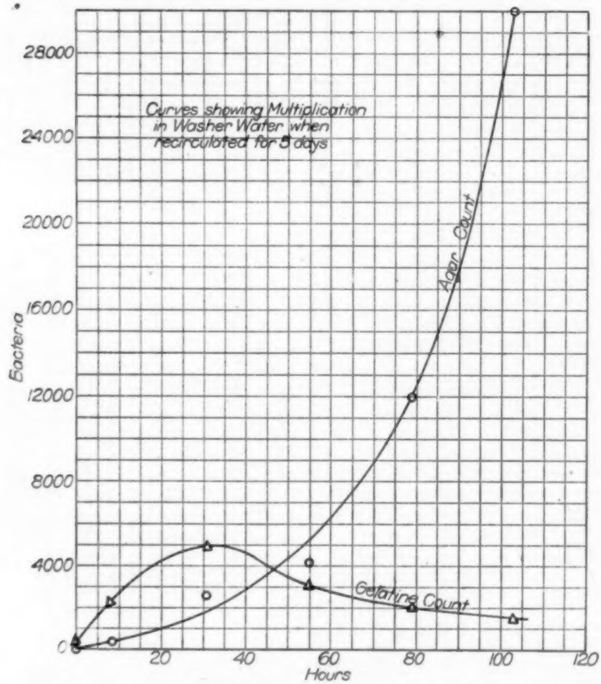



FIG. 10. CURVE SHOWING MULTIPLICATION OF BACTERIA WHEN WATER IS RECIRCULATED

er walls were covered with bacteria from the water used the previous week and hence the high count at the beginning of the following week. After March 16th fresh water was used continuously in the washer and tests were again taken March 25th and April 1st. These tests show an enormous decrease in the number of bacteria leaving the washer, but still most of the bacteria which came to the washer went through it.

After April 1st the water was changed daily and tests under these conditions were made on April 16th and April 23rd. The

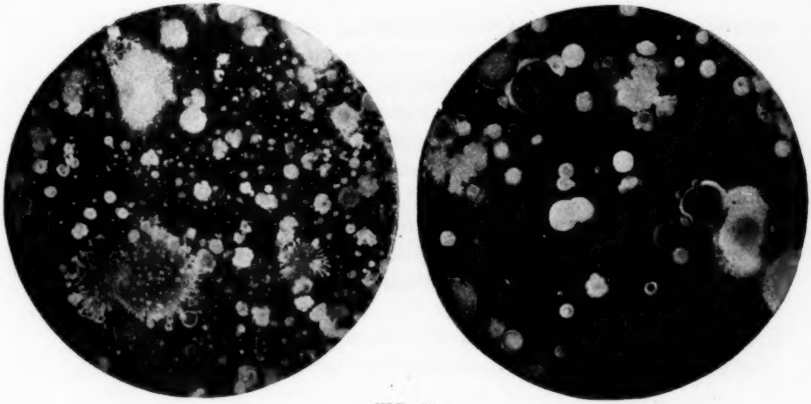


FIG. 11

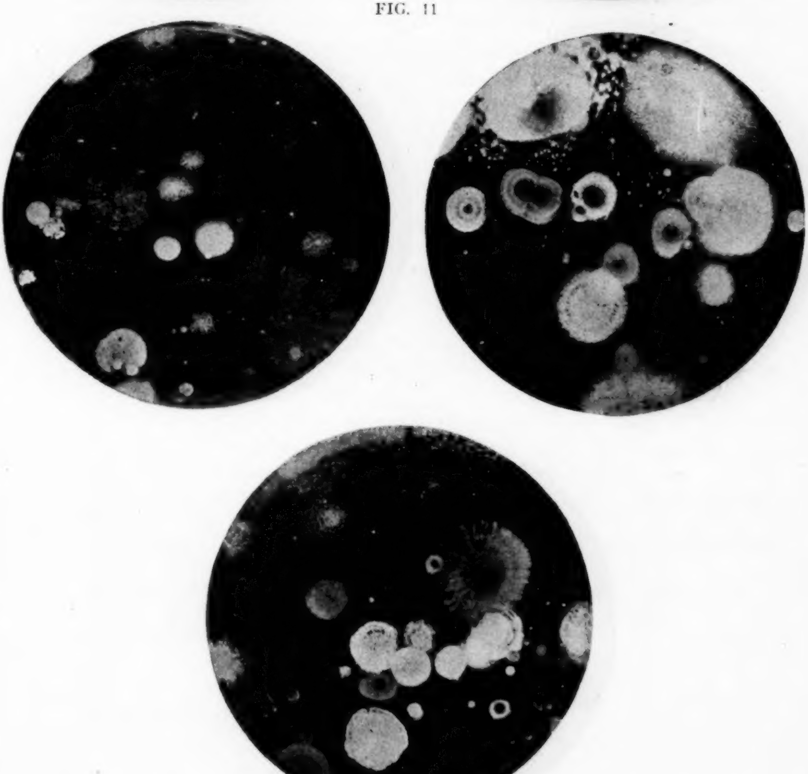


FIG. 12

results show no advantage in changing the water daily as the number of bacteria leaving the washer is almost as great as when the water was only changed weekly.

As a check upon the above results, Petrie plates were also exposed at the inlet and outlet registers of some of the rooms. Table VIII is a tabulation of these results. All of them show more bacteria coming into the rooms than going out.

Bacteria tests were also taken on the washer water. Table VII shows the multiplication of bacteria in the water when it is recirculated for a week and Fig. 10 shows the same in the form of a curve.

Table IX shows the results of plates exposed to the outside air. These were taken in comparatively still air and, when comparing

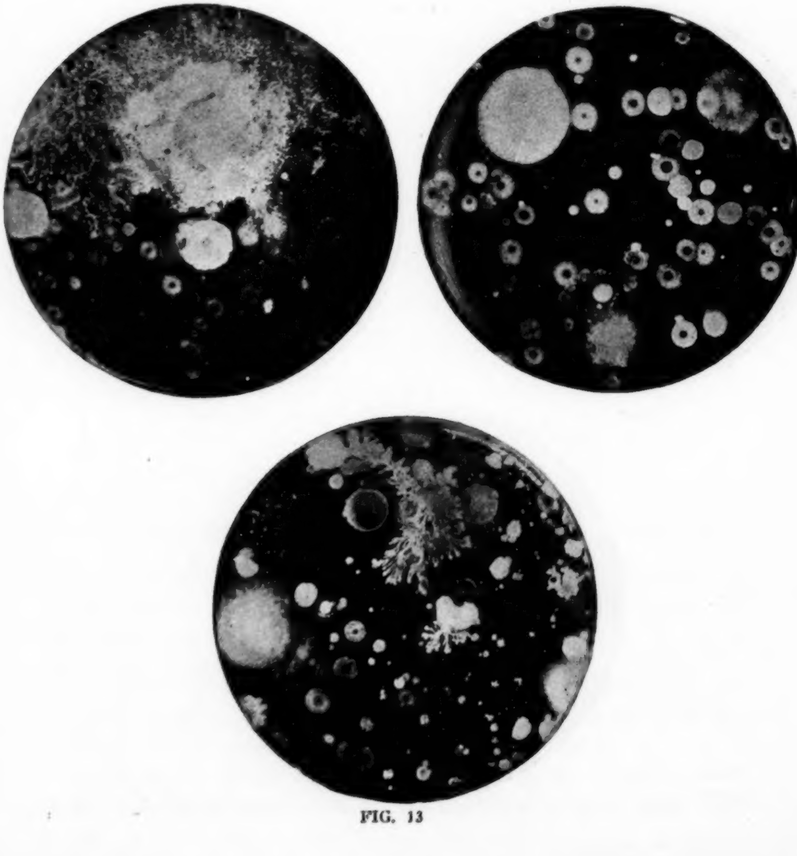


FIG. 13

them with the plates exposed in the ducts; the air velocity should be taken into consideration.

Fig. 11 is a photograph of two of the plates taken when the washer water was being recirculated for a week. No. 2 was exposed to the air after it had passed through the washer, and No. 3 was exposed to the air before it had passed through the washer.

Fig. 12 is a photograph of three plates taken after fresh water had been used continuously for ten days in the washer. No. 4 was exposed to the outside air. No. 5 was exposed to the air after it had passed through the washer, and No. 6 was exposed to the air before it had passed through the washer. All three were thirty minute exposures.

Fig. 13 is a photograph of three plates exposed after the washer water had been changed daily for ten days. No. 7 was exposed to the air before it had passed through the washer. No. 8 was exposed to the air after it had passed through the washer, and No. 9 was exposed to the outdoor air for the same length of time.

## CALCULATIONS

### CALCULATION OF WATER EVAPORATED IN WASHER

The figures used below are average values from a six hour test that was made to ascertain the amount of water used by the washer:

North Duct: Temperature of air 69.5 deg. Humidity 78 per cent. The weight of water vapor per cubic foot at 69.5 deg. and 78 per cent. humidity is 6.1252 grains.

South Duct: Temperature of air 70.3 deg. Humidity 72 per cent. The weight of water vapor per cubic foot at 70.3 deg. and 72 per cent. humidity is 5.801 grains.

### AFTER WASHING

Temperature of air, 65 deg. Humidity, 98 per cent. The weight of water vapor per cu. ft. at 65 deg. and 98 per cent. humidity, 6.6466 grains.

The weight of water vapor gained by air from North Duct is 6.6466 — 6.1252 = 0.5214 grains per cu. ft.

The weight of water vapor gained by air from South Duct is 6.6466 — 5.801 = 0.8456 grains per cu. ft.

Cu. ft. of air per minute passing through the North Duct, 5,780.

Cu. ft. of air per minute passing through the South Duct, 8,340.

Total weight of water gained by air from North Duct =

$$\frac{5780 \times 60 \times 0.5214}{7000 \times 8.3356} = 3.1 \text{ gal. per hour.}$$

Total weight of water gained by air from South Duct =

$$\frac{7000 \times 8.3356}{8340 \times 60 \times 0.8456} = 7.25 \text{ gal. per hour.}$$

Total weight of water given to air by washer under above conditions of temperature and humidity = 3.1 + 7.25 = 10.35 gal. per hour.

The washer tank dimensions are 8 x 5 x 1.25 ft. It was found by measurement that the water level decreased 2 in. in six hours, the make up water being shut off. Therefore, by actual measurement the water given to the air by the washer under the above conditions was 8 x 5 x 2/12 x 7.5 = 8.34 gal. per hour.

The discrepancy between the pounds of water actually measured and the pounds of water calculated from the humidity tables is probably due to the inaccuracy of humidity measurement.

The weight of washer water was obtained at the same time the above humidity measurements were taken. From these figures an interesting check on the volume of air passing through the washer can be made.

The average temperature drop in the air going through the washer was 4.9 deg. and the weight evaporated was 8.34 gal. per hour.

8.34 x 8.3356 = 69.52 lb. per hour.

The temperature of the washer water was 64 deg. and the latent heat of vaporization at 64 deg. is 1,056 B. t. u.

The volume of air which will be cooled 4.9 deg. by the evaporation of 69.52 lb. of water is approximately

$$\frac{69.52 \times 55 \times 1056}{4.9 \times 60} = 13{,}750 \text{ cu. ft. per minute.}$$

## COST OF WATER FOR AIR WASHING

To get the cost of air washing it is assumed that the cost of water is five cents per thousand gallons, as estimated by Mr. J. M. Smith from his cost data of operating University pumping plant, and that the washer is in service eight hours a day and five days a week. It is also assumed that, under the average running conditions, the air passing through the washer absorbs 10 gal. of water per hour and that the tank is filled to a depth of ten inches each time a change of water is made.

Make up water is admitted to the tank by a float valve.

*Condition No. 1*: Washer water recirculated for a week, beginning with fresh water each Monday morning. Cost of water per week:

$$\left[8 \times 5 \times \frac{10}{12} \times 7.5 + 10 \times 8 \times 5\right] \times \frac{.05}{1000} = \$0.0325$$

*Condition No. 2*: Washer water recirculated for 8 hours, beginning with fresh water each morning. Cost of water per week:

$$\left[\left(8 \times 5 \times \frac{10}{12} \times 7.5\right) \times 5 + 10 \times 8 \times 5\right] \times \frac{.05}{1000} = \$0.0825.$$

*Condition No. 3*: Fresh water used continuously. Under conditions No. 1 and No. 2 the water pressure on the spray nozzles averaged about 12 lb. per sq. in. gage. With 12 lb. pressure on the spray nozzles, measurements were taken to ascertain the cost of using fresh water continuously. With the drain from the tank closed it was found that it required two minutes for the water in the tank to rise 11 in. Therefore the fresh water required when used continuously would be

$$8 \times 5 \times \frac{5.5}{12} \times 60 \times 7.5 = 8250 \text{ gals. per hour.}$$

Cost of water per week:

$$8250 \times 8 \times 5 \times \frac{.05}{1000} = \$16.50$$

COST OF POWER FOR RECIRCULATING WASHER WATER

Average power required to drive the centrifugal pump, 2.41 k. w.
Cost of this power for a week, 2.41 x 8 x 5 x 0.025 = $2.41.
Total cost of running the washer:

2.41 + .0325 = $2.4425 for Condition No. 1.
2.41 + .0825 = $2.4925 for Condition No. 2.
$16.50 for Condition No. 3.

CALCULATION OF THE ECONOMY OF RECIRCULATION OF AIR

In each of the runs made the air leaving the washer and entering the rooms was at an average temperature of about 60 deg. The average outside temperature during the time the fan was running was 25.4 deg., 30.5 deg., and 27 deg. respectively for the first, second and third tests. The total amount of air delivered to the rooms in each case was approximately 15,000 cu. ft. per minute. If this air had been taken from the outside instead of being recirculated, the additional steam required would have been

$$\frac{60 \times 15000}{55 \times 960} \times (60 - 25.4) = 590 \text{ lbs. per hour for the first test.}$$

The above calculation is based on the following figures:

The average steam pressure on the building during all three tests was 5.3 lb. gage and the average temperature of the condensed steam leaving the building was 209 deg. The quality of the steam entering the building averaged 98 per cent. Therefore each pound of steam gave up .98 x 960 + 196.1 — (209 — 32) = 960 B.t.u. It is assumed that one B.t.u. will raise 55 cu. ft. of air one degree of temperature.

The additional steam required for the second test would have been

$$\frac{60 \times 15000}{55 \times 960} \times (60 - 30.5) = 503 \text{ lbs. per hour and for the third test:}$$

$$\frac{60 \times 15000}{55 \times 960} \times (60 - 27) = 562 \text{ lbs. per hour.}$$

The actual weight of steam used by the building during the time the fan was running was 834.6, 573.1 and 824 lb. per hour for the first, second and third tests, respectively.

The percentage of steam saved by recirculation of air in each case:

$$\frac{590}{590 + 834.6} = 41.4 \text{ per cent. for the first test.}$$

$$\frac{503}{503 + 573.1} = 46.5 \text{ per cent. for the second test.}$$

$$\text{and } \frac{562}{562 + 824} = 40.5 \text{ per cent. for the third test.}$$

Since the fan in actual practice is only operated eight hours out of 24, the saving from recirculation will not be as much as shown above.

Running the fan eight hours the saving for the entire 24 hour period will be:

$$\frac{8 \times 590}{8 \times 590 + 23161} = 16.8 \text{ per cent. from the first test and}$$

$$\frac{8 \times 503}{8 \times 503 + 16988} = 19.2 \text{ per cent. from Test No. 2.}$$

### THE EFFECT OF THE FAN UPON THE STEAM CONSUMPTION

#### TEST NO. I

(Febrary 2nd and 3rd)

The total weight of steam used by radiators when the fan was in operation was 6676.5 lb., or an average of 834.6 lb. per hour for eight hours. Total weight of steam used when the fan was not in operation was 16483.5 lb., or an average of 1030.2 lb. per hour for 16 hours. The difference in average steam consumption is 1030.2 — 834.6 = 196.2 lb. per hour in favor of the fan.

Since some of the above saving may be due to unequal outside temperatures during the two parts of the run, it is best to base the relative performance on the basis of per degree difference of temperature.

Average pounds of steam per hour per degree difference of temperature while fan was in operation is 19.8 lbs.

Average pounds of steam per degree difference of temperature per hour during time when fan was not in operation is 26.64 lb. The difference is 6.84 lbs., or a saving of $\frac{6.84}{26.64} = 25.7$ per cent. in favor of running the fan.

#### TEST NO. II

(February 27th and 28th)

Total weight of steam used by radiators during the time the fan was in operation was 4,585 lb., or an average of 573.1 lb. per hour for eight hours. The total weight of steam used during the time the fan was not in operation was 12,403 lb. or an average of 775 lb. per hour for sixteen hours. The difference in average steam consumption is 201.9 lb. per hour.

Average pounds of steam per hour per degree difference of temperature during time that fan was in operation = 16.18 lb.

Average pounds of steam per degree difference per hour during time the fan was not in operation = 17.66 lb.

The difference is 1.48 lbs., or a saving of $\frac{1.48}{17.66} = 8.38$ per cent. in favor of running the fan.

#### TEST NO. III

(March 3rd and 4th)

Total weight of steam used by radiators during the time the fan was in operation was 16,485 lb., or an average of 824.2 lb. for twenty hours. Total weight of steam used by the radiators during the time the fan was not in operation was 6,369 lb., or an average of 910 lb. per hour for seven hours.

Difference in average steam consumption = 86 lb. per hour.

Pounds of steam per hour per degree difference during time the fan was in operation = 21.54.

Pounds of steam per hour per degree difference during the time the fan was not in operation = 23.81.

The difference is 2.27 lbs., or a saving of $\frac{2.27}{23.81} = 9.53$ per cent. in favor of running the fan.

A COMPARISON OF THE SAVING MADE BY KEEPING THE AIR IN MOTION AND THE COST OF OPERATING THE FAN

Will it pay to operate the fan continuously? To answer this question the following calculations have been made:

The cost of steam delivered to the building is approximately 27c per thousand lbs. and the cost of power is approximately 2½c per kilowatt hour.

According to the figure obtained from the first test a saving of 25.7 per cent. in steam consumption was made by running the fan to keep the air in motion. The total pounds of steam used during the sixteen hours that the fan was standing idle was 16,483.5 lbs. Had the fan been running during this period a saving of 16,483.5 x .257 or 4,235 lbs. of steam would have been obtained.

$$\text{Cost of steam saved} = \frac{4235}{1000} \times 0.27 = \$1.144.$$

$$\text{Cost of operating the fan} = \frac{516 \times 7.85}{1000} \times 16 \times .025 = \$1.62.$$

The saving in the second test would have been 12403 x .0838, or 1040 lbs. of steam.

$$\text{Cost of steam saved} = \frac{1040}{1000} \times 0.27 = \$0.28.$$

$$\text{Cost of operating the fan} = \frac{1000}{518 \times 8} \times 16 \times .025 = \$1.656.$$

The volts and amperes used in the above calculations are average values of the power consumption of the fan motor.

The third test would show about the same relative cost as the second test.

The second and third tests probably give the fairest idea of the saving of steam obtained by keeping the air in motion. Obviously the cost of power for the fan more than overcomes the saving resulting from its use.

In all of the tests the air temperature was reduced about 6 deg. in passing through the washer. If the washer had been shut down during the time there were no students in the building, a greater saving of steam would have resulted from keeping the air in motion. But even under such conditions, the saving would not have been enough to overbalance the cost of power for the fan.

Take Test No. 2 for comparison. In this test the saving that would result from running the fan and washer for the additional sixteen hours was shown to be 1040 lb. of steam. The drop of temperature in the washer was 6 deg.

and the air passing through it was 15,000 cu. ft. per minute. The extra steam consumption required to replace the heat taken away by the washer water was $\frac{6 \times 15000 \times 60}{55 \times 960} = 102$ lb. per hour, or a total of 1635 lb. for the sixteen hours.

Therefore, with the fan running and the washer cut out, the total saving of steam would have been 1040 + 1635, or 2675 lb. The cost of this steam would be $\frac{2675}{1000} \times 0.27 = \$0.72$ as compared with \$1.656 for power to run the fan.

The steam cost used in the above calculations is below the average and there may be conditions where high steam cost and low power cost will justify the running of the fan continuously.

Lack of time made it impossible to check these last calculations with an actual test of steam consumption for recirculated air with the washer cut out. It would be interesting to see how it would work out in actual practice.

### STEAM USED PER SQUARE FOOT OF RADIATION PER HOUR

The steam consumed by the radiators per square foot of radiation per hour in the first test was $\frac{23161}{24 \times 8530} = 0.113$ lbs.

$$\frac{16988}{24 \times 8530} = 0.083 \text{ lbs. for the second test}$$

$$\text{and } \frac{22854}{27 \times 8530} = 0.0993 \text{ lbs. for the third test.}$$

The average for the three tests is 0.0984, or approximately 1/10 lb. of steam per square foot of radiation per hour.

Since an average radiator will condense ¼ lb. of steam per square foot per hour under extreme conditions the results show that the building has ample radiating surface for any conditions which may arise.

### TOTAL COST OF HEATING AND VENTILATING THE BUILDING FOR A TYPICAL DAY OF 24 HOURS

*Data Taken from Test No. 1*

Cost of washer water $= \frac{0.0325}{5} = \$0.0065$.

Cost of power for washer pump $= \frac{2.41}{5} = \$0.48$.

Cost of power for ventilating fan $= \frac{518 \times 7.85}{1000} \times 8 \times .0252 = \$0.81$.

Cost of steam for heating = 23161 x .27 = \$6.253.

Total cost per day = \$7.55.

To the above total cost should be added the cost of running the two small exhaust fans in the attic.

The hot water tanks were cut out during the tests so that no data is available for the cost of steam for heating water.

The recirculating system was put into operation at the beginning of school, September 1914, and was in operation throughout the whole school year. The principal tests were made in the months of January, February and March, and the last of the bacteria tests was made in April.

The questionaire was submitted to the teachers on May 13th and the reports were handed in by them about three days later. This was about two weeks before school closed, the teachers having had nine months to form their conclusions in regard to the system. An interesting point in regard to the system came out about two weeks ago (Sept. 1915). The fan motor burned out and it took several days to get it into running condition again. The teachers were not aware that anything had happened but complaints soon began to pour in that there was something wrong with the ventilation.

### QUESTIONAIRE SUBMITTED TO TEACHERS

A questionaire was submitted to the various teachers in the school in order to get their opinion of the system and its effect upon the students. The questions were as follows:

1. Has your room been sufficiently heated?
2. Has the ventilation been satisfactory?
3. Has the air in the room been too moist or too dry?
4. Has the moisture in the air had a good or bad effect upon the quality of the air in the room?
5. If the moisture has had a bad effect please state what the effect is.
6. Has the room seemed close?
7. Have you noticed any unpleasant odors?
8. Have the students been bright and alert or drowsy and listless?
9. How does the ventilation in this building compare with that of other buildings in which you have taught?
10. How does the general health and alertness of the students in this building compare with that of students in other buildings in which you have taught?

### RESULTS FROM THE QUESTIONAIRE

Question No. 1.

All of the fifteen teachers answered "yes".

Question No. 2.

Twelve teachers answered "yes".

Teacher J answered "nearly so", Teacher M, "no".

Teacher N, "In the morning, yes; in the afternoon, no".

Question No. 3.

Teacher A—"Rarely too moist".
Teachers B, G, I and K—"No".
Teachers C, D and H—"Neither".
Teacher E—"If anything, too moist at times".
Teacher F—"Yes".
Teachers J and N—"A little dry".
Teachers L, M and O—"Just right".

Question No. 4.

Ten teachers answered "Good".
Teacher A—"Not strictly bad at any time".
Teacher B—"Apparently good".
Teacher F—"Did not notice."
Teacher L—"Have not noticed any bad effects."

Question No. 5.

No statements given by any of the teachers.

Question No. 6.

Teachers A and C—"Only when it is first opened in the morning".
Teacher B—"Very seldom".
Teachers D and G—"No".
Teacher E—"No, until recently".
Teacher F—"Not usually".
Teacher H—"In warm weather if windows are closed, yes".
Teacher I—"At times windows have had to be opened".
Teacher J—"A little".
Teacher K—"No, except in the morning before the fan had run sufficiently".
Teacher L—"Sometimes".
Teacher M—"In room No. 115, no; in room No. 311, yes".
Teacher N—"Yes".
Teacher O—"Not often".

Question No. 7.

Twelve teachers answered "no".
Teacher M—"Room No. 115, no; room No. 311, yes".
Teacher N—"Yes".
Teacher O—"Seldom".

Question No. 8.

Six teachers answered "Bright and alert".
Teacher G—"Depends more on students than on room conditions".

Teacher H—"Neither, some of each in each class."
Teacher I—"Not drowsy and listless as a rule".
Teacher J—"Both, but listlessness not due to ventilation".
Teacher K—"We have both kinds, but the room conditions did not make them so".
Teacher L—"Attitude varies".
Teacher M—"Both".
Teacher N—"Bright in morning; drowsy from 2:30-3:30 P. M.".

Question No. 9.

Six teachers answered "Better".
Teacher A—"Infinitely better".
Teacher B—"Better (have taught in six schools").
Teacher C—"Most favorably".
Teacher D—"Best in my experience".
Teacher E—"There is much more moisture in the air".
Teacher K—"Excellent".
Teachers M and N—"Favorably".

Question No. 10.

Teachers A and G—"Better".
Teacher B—"Much better".
Teachers C, I and L—"Favorably".
Teacher D—"Have not noticed health especially. Should call alertness better than usual class".
Teacher E—"Have no data".
Teacher F—"Don't know of any".
Teacher H—"Not so alert here, health better".
Teacher K—"About the same, perhaps somewhat better".
Teachers M and O—"About the same".
Teacher N—"Better than elsewhere".

## CONCLUSIONS

1. The tests show that it is both unnecessary and uneconomical to supply large volumes of air to obtain good ventilation.

2. That 15 cubic feet per student would be ample providing it enters the room at a fairly high velocity and carries the proper amount of moisture.

3. With humidity ranging from 50 to 70 per cent., the occupants of the rooms are perfectly comfortable at a temperature of 65 degrees or even less.

4. With humidity of about 60 per cent., the air can enter the rooms at a temperature of 60 degrees without creating any dis-

comfort; in fact it seems to give life to the air and aids in the efficiency of ventilation.

5. Carbon dioxide content as high as 20 parts in 10,000 does not have a bad effect upon the ventilation.

6. Ventilation by recirculation is both efficient and economical. At the end of a year's run the teachers are almost unanimous in their praise of the system.

7. With a recirculating system such as this, it requires from 40 to 50 per cent. less steam to heat the building while the fan is in operation than would be required if the air was drawn from outdoors for the same length of time.

8. Air movement keeps the temperature uniform in various parts of the room and decreases the amount of steam required for heating. The tests show a minimum saving of about 8 per cent. due to this air movement and this would be true whether the system is a recirculating one or otherwise.

9. The air washer absorbs a considerable amount of the carbon dioxide contained in the air passing through it.

10. The air washer is apparently quite efficient as a dust remover but it does not remove bacteria from the air when the washer water is recirculated. The tests show that it actually supplies bacteria to the air under such conditions.

11. In spite of the poor showing of the washer, the air entering the rooms carries no more bacteria than outside air when the relative velocities in which the plates were exposed is taken into account.

The writer plans to continue these tests this coming winter with a view of ascertaining the effect of recirculation upon the oxygen content of the air. Further tests will also be made to determine more accurately the amount of carbon dioxide absorbed by the washer, and experiments will be carried on with various methods of eliminating bacteria from the washer water.

## ADDENDUM*

A few words of explanation may be added in regard to the low values of carbon dioxide found in the tests. The writer makes no assumption that the building is air tight. The tests were made under actual conditions as they exist at the school. The windows are of such construction that less leakage takes place than is usual in most school buildings, and careful observations of the building showed that none of the windows were open during the test or during most of the school year.

* Added on the recommendation of the Publicatiton Committee.

But of course leakage took place, and in accounting for the low values of carbon dioxide found, the following points must also be borne in mind:

Room No. 15 (see Table I), which is the gymnasium, was occupied only late in the afternoons, and whatever leakage that took place into this room during the day was distributed through all the other rooms of the building by means of the recirculating system.

The same is true of the Auditorium, Room No. 214. The Auditorium was used only for assembly periods two or three times a week and then only for an hour a day. At all other times the leakage into this large room was distributed through all the other rooms. And, during assembly periods, all the classrooms are unoccupied and a large part of the leakage into them finds its way into the Auditorium.

The same action takes place from Rooms No. 108 and No. 209. These rooms are small auditoriums which are only used for short periods once or twice a week.

There was an average attendance of about 250 students in the building throughout the school year. The figures in Table I are based upon the student capacity of the rooms and not upon the actual attendance.

The average attendance for the year for the various class rooms is given below.

| Room Number | Student Capacity of Room | Average Attendance |
|---|---|---|
| 8 | 20 | 16 |
| 10 | 28 | 16 |
| 106 | 26 | 20 |
| 107 | 26 | 11 |
| 109 | 26 | 20 |
| 115 | 31 | 26 |
| 207 | 31 | 22 |
| 208 | 26 | 17 |
| 210 | 26 | 20 |
| 211 | 31 | 23 |
| 213 | 20 | 17 |
| 308 | 41 | 20 |
| 309 | 25 | 16 |
| 311 | 15 | 14 |
| 312 | 14 | 14 |
| 314 | 29 | 16 |
| | Average 26 | Average 18 |

## DISCUSSION

GEO. T. PALMER: The ideal experiment is one in which full sized equipment is used and actual operating conditions are duplicated. Prof. Larson has been able to conduct his work under these conditions, so that results are therefore of special moment.

The essential features of this study are that an entire school building has been ventilated apparently in a satisfactory manner for a full season with recirculated, washed air, at a material saving in the consumption of coal. This economic feature is most attractive and is in entire agreement with Dr. McCurdy's experience at the Springfield Y. M. C. A. Gymnasium. When ventilating methods are proposed that involve a reduction in fuel cost of from 20 to 50 per cent., they are worthy of most careful scrutiny.

We are at once tempted to inquire, however, whether there is not some sacrifice we must make in comfort, or some advantage we must surrender in return for this reduced operating expense. The votes of the teachers shed some light on this question. While it is true in general that the replies are most complimentary to the system and that there is universal agreement in the superiority of the ventilation of this school building over the ordinary type, yet in answer to the query about "closeness," out of 15 answers, only 4 were unqualifiedly favorable. Also 3 out of 15 teachers report unpleasant odors in their rooms. It must also be borne in mind that these Wisconsin pupils are of high school age and are superior to the ordinary child of the public schools in cleanliness and matters of personal hygiene. If odor and closeness occur under these Wisconsin conditions, I doubt whether recirculation would have been as successful in some of the crowded public schools of this city.

In connection with the use of re-circulated air I note that air washing is always spoken of as a necessary part of the process. Personally, I question whether washing itself is efficacious in removing odor. I believe that dilution is the big factor in the success of re-circulation. Both Prof. Larson and Dr. McCurdy of the Springfield Y. M. C. A. Training School have found re-circulation successful. At Wisconsin, however, classrooms are occupied only to about 75 per cent. of their capacity and the air from these rooms has ample opportunity to become diluted with the air from corridors, assembly hall and gymnasium. Likewise

the Springfield gymnasium has a comparatively small number of occupants for the large cubic space ventilated.

It has been the experience of Prof. Bass and ourselves in ventilating a single room where there is but slight dilution, that odors are not removed by washing. In fact, we in New York have found that washing intensifies the odor—that odor is less apparent with the washer shut down. The lower the humidity the less perceptible is the odor.

The use of higher humidities has one possible objection that was brought to my attention recently. I was sitting in a classroom at a temperature of 68 deg. and 50 per cent. relative humidity; this felt too warm and moist. I opened one or two windows slightly from the top; the incoming cold air felt quite chilly and I closed the windows somewhat. During the next 20 minutes at least ten persons in the room sneezed, I among the number. The combined warmth and moisture had, I believe, produced slight perspiration over the body and evaporation of this moisture by the cold air caused a chilling of the body that I am very sure would not have occurred had the room been drier. This experience suggests a danger of higher humidity whenever slight overheating occurs.

As to the absorption of carbon dioxide by the wash water, it is contrary to our own experience here and also to that at Springfield. A possible explanation of this may be found in the character of the water used. In the East where surface water supplies are used, the alkalinity of the water is low. In deep well water, the alkalinity is high, amounting at times to several hundred parts per million. It is conceivable that this high alkalinity will actually react with carbon dioxide in the gaseous form and thereby reduce the carbon dioxide content of the re-circulated air.

The increase of bacteria in the wash water seems pretty well substantiated but it is believed that the counts at the register inlet in the classroom indicate the extent of this increase more exactly than the samples taken from the fan inlet or plenum chamber in the basement. In the latter instance it seems likely that droplets of water passing the eliminator plates might infect the plates heavily but that this same bacterial population would not be carried to the room. Any danger in re-circulated air from this source is rather scouted however.

The use of high register velocities as described is unique and its efficacy in adding comfort to the environment is supported by our own experience. We have found that well defined air

currents in a room are appreciated much more than increased volume of air at low velocities even though thoroughly distributed over the room.

I trust that my discussion of Prof. Larson's paper will not seem too critical. Re-circulated air or at least a mixture of re-circulated and fresh air, can without doubt be used advantageously in many instances. My intent has been rather to issue a word of caution lest the economy of the practice be permitted to outweigh considerations of comfort to which primarily the occupants of the ventilated space are entitled.

MELVILLE C. WHIPPLE: Having gone over the portion of the paper dealing with bacteria removal by washing I cannot see where there is a great deal of chance for argument. It is simply a case of obtaining results which on the face of them do not appear consistent and which cannot be explained away by any information at hand.

I have never made determinations for bacteria in washed air which showed a larger number than in the unwashed air. On one occasion, however, I found at Springfield that the number of dust particles was slightly higher in the washed than in the unwashed air. This was after the water had been used for several weeks and was extremely dirty. After such conditions it might be that the bacteria would be slightly higher in the washed air, but I have never found this to be the case although some of the washers studied in Boston had extremely dirty water.

I would be inclined to take objection to Mr. Larson's conclusions Nos. 10 and 11. If dust is removed from the air as he states in No. 10 then the bacteria certainly ought to be removed. It is up to him to explain or show why they are not by his future experiments. In connection with No. 11 it seems to me that so far as bacteria go, the air in the room is the same as the outside air until the rooms are occupied, after which time the bacteria increase in number because of contamination incident to occupation. If the air in the room contains more bacteria than the outside air then certainly this air after washing is not as good as outside air, provided, as Mr. Larson says, bacteria are introduced into it and not removed from it.

These experiments show very few determinations with our standard method which employs a sand tube. I should be inclined to discount the results obtained by the exposure of plates, particularly as the plates were exposed for such a long

time that very large numbers of bacteria developed on each plate. We calculate in bacteriological work to count plates which have less than 300 bacteria upon them.

This set of experiments by Mr. Larson is a very valuable one in my estimation. The installation has given opportunity to study many of the things which we were interested in at Springfield and I should judge in a more exact manner. It is particularly interesting to note that the work indicates economy where re-circulation is employed.

PROF. G. C. WHIPPLE: I was very much interested in Prof. Larson's paper on re-circulation of air, as apparently he has had an excellent chance to try out the method. I cannot understand why he failed to secure bacterial removal with the air washing process. Our bacterial results have always been consistent without dust counts. There are many things to learn, however, and I hope that not only he but many others will try out the method.

THE AUTHOR: Replying to Mr. Whipple's remarks, the author wishes to state that no dust counts were taken on account of lack of apparatus for carrying on such work. Judging from the discoloration of the washer water and the sediment in the tank the washer undoubtedly removed dust from the air, but its efficiency in this respect can only be measured by actual dust counts. If particles of the contaminated water pass the eliminator plates it is quite possible that the bacteria results will not be consistent with the dust counts. In a re-circulating system of this kind the solid particles carried by the air are to a large extent composed of fresh chalk dust from the blackboards. Under such conditions the author questions the statement that the bacteria counts should be consistent with the dust counts.

The writer fully realizes that plate exposures are only approximate quantitative measures of the number of organisms present, and the method was used primarily to show the relative effects of changing the washer water. The sugar filters were used with two points in view, namely, for comparative purposes—that is to say, to compare the effectiveness of the method with the sand filter procedure, and as a check on the efficiency of the air washer. The standard sand tube method was used daily for a week's run and our main reliance, relative to conclusions, was based on this method. It is the purpose of the author to continue the experiments using only standard sand filters for all bacteria measurements.

Mr. Palmer expresses the writer's own opinion in regard to the relative bacteria counts at the fan inlet and at the room inlets. The tabulated results show that the bacteria count at the fan inlet varied with the cleanliness of the washer water. This would seem to indicate that water was getting past the eliminators, and undoubtedly a large number of these bacteria were deposited on the moist surfaces of the ducts leading to the rooms.

No. 406

# A NOTABLE INSTITUTION FOR THE ADVANCEMENT OF THE HEATING AND VENTILATING ART

By Arthur K. Ohmes, New York

Member

THE recent appointment of committees on publicity and education to advance the art of heating and ventilating has been the inspiration for the writing of this article, which will have for its subject the so-called Testing Institute for Heating and Ventilation appliances at the Berlin University. The work done in this Institute has been several times mentioned in the Transactions of this Society and the writer believes that a fairly complete description of it, will prove interesting to the membership and to the members of the educational committees.

This Institute is to the writer's knowledge the most complete, up-to-date and best equipped for the purpose, and it is solely devoted to the advancement of the art of heating and ventilation.

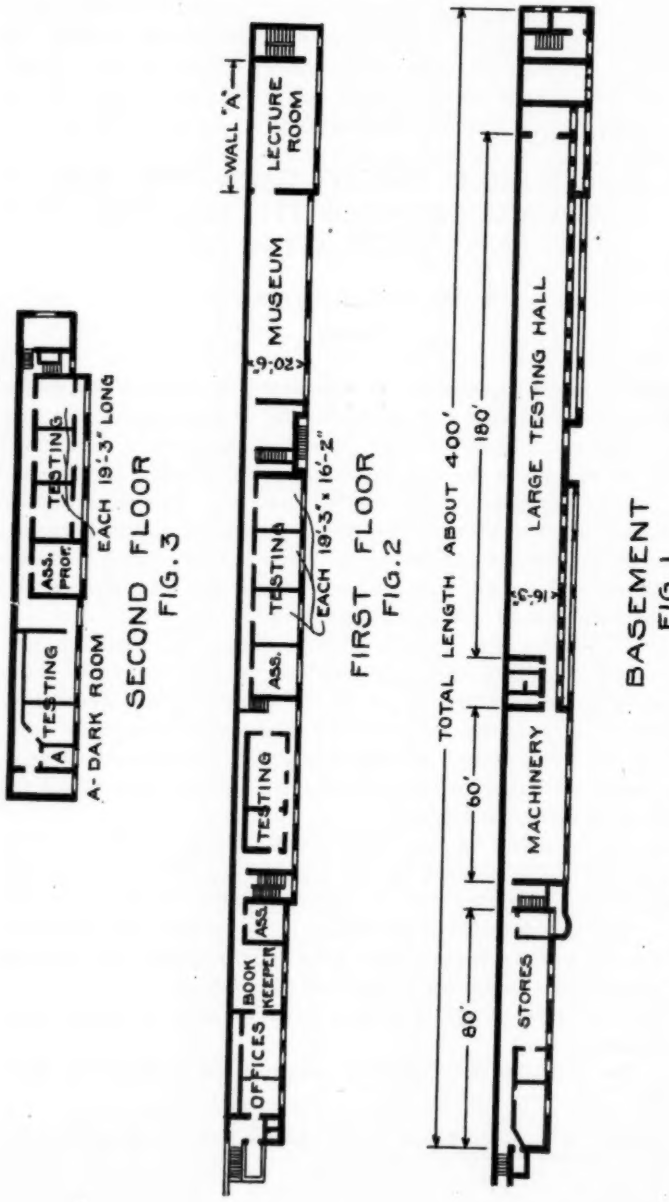
Our country, so much advanced in many ways, possesses nothing of the kind, though the importance of the industry of heating and ventilation in this country far exceeds that of all the leading countries of Europe.

No doubt many of our institutions of higher education do not consider the subject of heating and ventilation of enough importance to warrant such an institution, but Germany appears to be fully alive to the importance of the subject and considers that accurate knowledge of the art vitally concerns the physical as well as the commercial welfare of the people.

The ambitious program of this Institute may be summarized as follows:

1. The scientific education of heating and ventilating engineers.

Presented at the Annual Meeting of The American Society of Heating and Ventilating Engineers, New York, January, 1916.




FIGS. 1-3. FLOOR PLANS OF THE TESTING INSTITUTE AT BERLIN UNIVERSITY

2. To teach the future architects the fundamental principles of heating and ventilation—a knowledge required by them for the proper designing of buildings.

3. The testing of all kinds of heating and ventilating appliances for the purpose of determining the capacity and efficiency, statements of manufacturers, inventors, etc.

4. Scientific research work.

The educational work (1 and 2) follows closely along the lines of the famous book of Prof. Rietschel. The results of testing appliances of private concerns and corporations are mostly confidential until such time as the makers or inventors of the appliances are willing that the results should be made public.

As a result of these tests the Institute often makes suggestions to manufacturers, etc., that lead to improvements. It is safe to say, however, that many new inventions that were tested out to the entire satisfaction of the maker in the private plant did not prove so satisfactory in the tests at the Institute.

The Institute charges a small sum of money for making tests and in view of the specially fitted out quarters, and that the latest and most accurate instruments only are used, almost all tests can be made better and cheaper in the Institute than in most private plants.

The writer is strongly of the opinion that many tests made in this country are not made under the conditions that are to be found in such an Institute and that much of the criticism now directed against heating and ventilating plants in this country is quite often due to the careless and unscientific way in which a great many tests are made which form the basis of a large part of the practice in the art.

The research work done by the Institute (No. 4), however, is the most important for the practical heating and ventilating engineer and this will be described later on.

### DESCRIPTION OF THE INSTITUTE

The Institute's origin is due to efforts of the late Professor Rietschel, who started it in a very modest way, some twenty years ago.

In 1907 a large testing hall, 180 feet long was added and this year, on June 18th, another large section was put in operation. The Institute in its entirety as it appears at the present time is shown in Figs. 1 to 3. These plans have been reproduced from the Gesundheits-Ingenieur 1915, all writing being translated by the author for an easier understanding. Fig. 4 shows an exterior view.

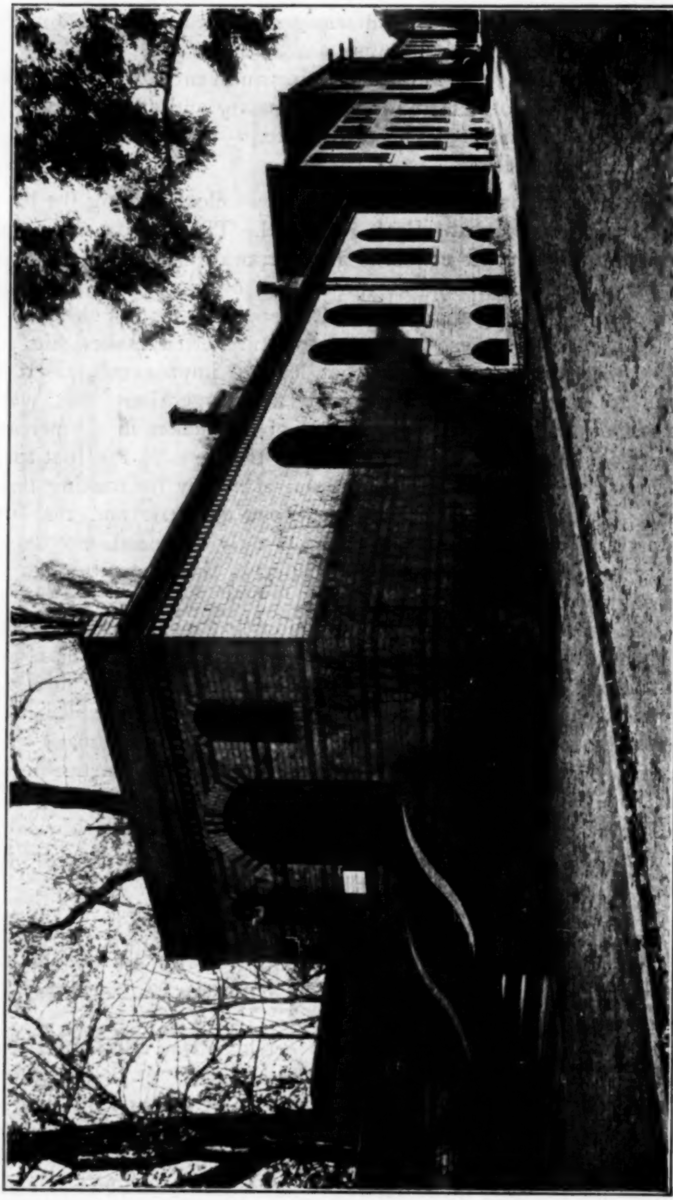


FIG. 4. EXTERIOR VIEW OF THE INSTITUTE.

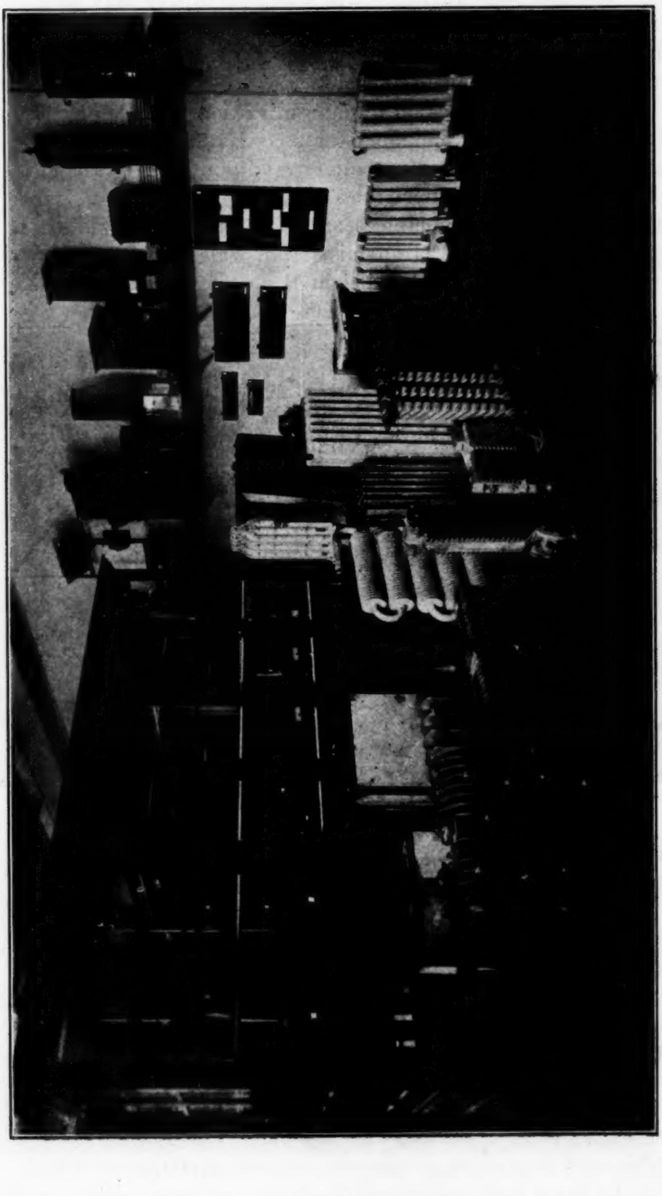


FIG. 5. INTERIOR VIEW OF THE MUSEUM.

Note the spacious quarters in a building of 400 feet length; one room alone being 180 feet long. There are five inside smaller testing rooms and five testing rooms with outside windows. There is also a museum, the inside view of which is shown in Fig. 5, where the most up-to-date inventions are kept along with many venerable appliances for record and for showing the advancement of the art. Immediately adjoining it is the large and well ventilated and mechanically cooled lecture room, which seems to be the most complete and best one ever installed in Germany. Even the heat transmission of wall "A" (Fig. 2) was taken care of by pipes imbedded in the construction as shown

FIG. 6. AN ARRANGEMENT OF PIPES IMBEDDED IN WALL.

in Fig. 6. There is a well stocked library as well as offices for professors, the assistants, bookkeepers, etc. A general interior view of the large testing room is shown in Fig. 7, which view was taken when the friction coefficients of hot water pipes were being determined as described by Prof. Giesecke in the Society's Journal for April, page 24.

The building was erected by the Prussian State Government assisted by the help of the interested private business men and various leagues throughout Germany.

It is, therefore, a National Institution and is so recognized by the entire heating industry of Germany, which includes the installing and engineering concerns, the manufacturers of specialties, the great iron works manufacturing radiators, pipes, etc.,

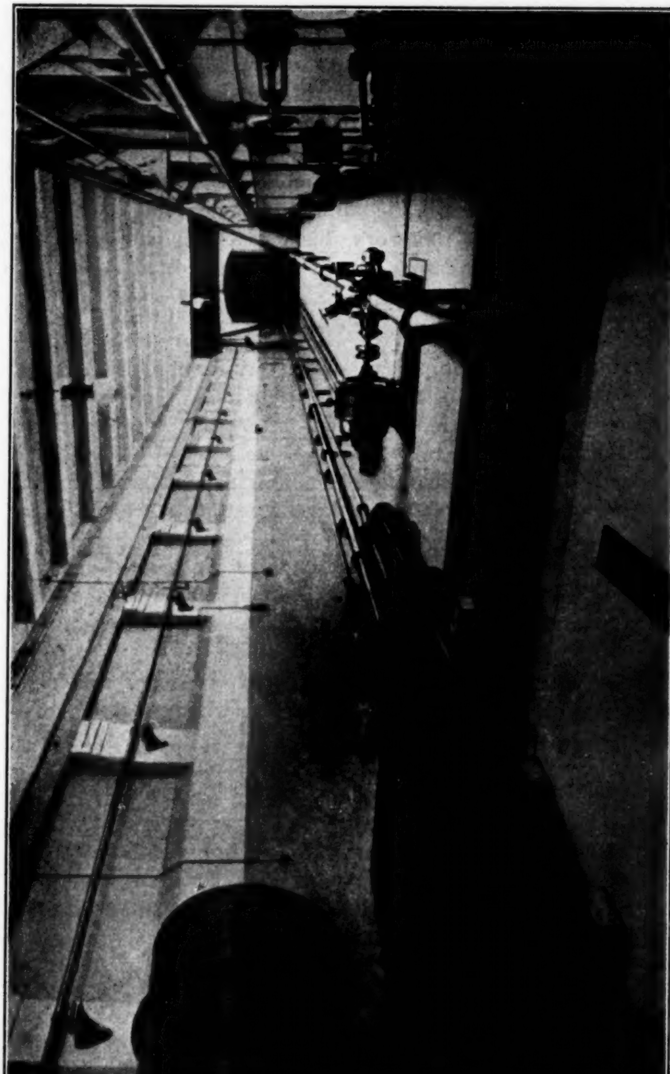


FIG. 7. VIEW IN THE LARGE TESTING HALL.

who helped to make it a success and believe in it as an indispensable Institution.

The Institute is at present headed by Dr. Brabbee, who is assisted by six trained scientists and assistant professors, all of whom are interested only in heating and ventilating work—certainly an array of talent unheard of in this country.

### A FEW REMARKS ON THE RESEARCH WORK

Before the Institute was completed, important research work had already been accomplished in the old and close quarters.

The most important of this work, that which is of interest to the entire heating and ventilating art, is published in a series of pamphlets as follows:

1. Introductory words by Prof. Rietschel, description of testing Institute and its equipment and determination of velocity and pressure conditions of air flowing in ducts.

2. Tests on traps, thermostats, ventilating caps and efficiency tests of a Strebel boiler.

3. Tests to determine heating effect, pressure loss and surface temperature of radiators with air traveling at high velocity over same.

4. Test on one-pipe systems of forced hot water heating and calibration of a steam meter, statement of cost of making tests, influence of radiator enclosures on the heating efficiency of radiators and a description of newer radiators.

5. Test of friction resistance, etc., in hot water heating systems.

6 and 13. Simplified method for graphical and numerical methods for determining pipe sizes for high and low pressure steam heating systems.

7. Efficiency test of a Lollar boiler.

8. Test of a Schotter blower.

9. Test of air revolving systems of the low pressure steam heating type.

10 and 12. Test of safety devices of hot water heating boilers.

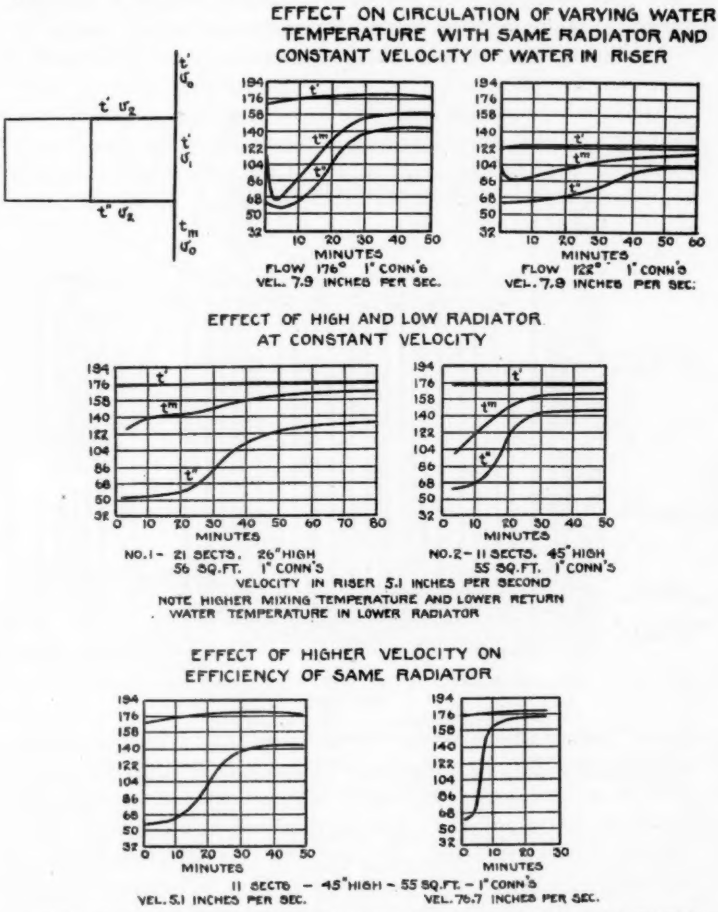
11. Simplified method for graphical and numerical methods for determining ventilating plants.

The cost of these pamphlets is exceedingly modest, covering only a very small profit beyond the cost of production. This is easily possible because the tests are made by state employees, with the help of students.

Only our own government's publications such as the Bureau of Mines, can be compared in cheapness and quality with

them. Some of these publications are voluminous and the pamphlet No. 5, covering hot water friction and resistance coefficients, would fill more than one issue of the Societies' Journal.

Accordingly, it cannot be expected that any of the tests be




FIGS. 8-14. SKETCHES FROM TESTS ON ONE-PIPE FORCED HOT WATER HEATING SYSTEMS.

given here in full, though this article would scarcely be complete without some general descriptions.

We will first consider the diagrams 8 to 14 of the test on one-pipe systems of forced hot water heating circulation as described

in pamphlet No. 4. These sketches show graphically the three fundamental conditions—temperature, height of radiator and velocity of water in riser—governing the secondary flow of water through the radiator itself. A little study of the foot notes under each pair of figures will prove of interest and with the clear graphical representation further comments are unnecessary.

An illustration of how this Institute may be of service is given in the following:

About ten years ago some "air revolving" low pressure steam heating systems were patented in Germany. The steam is led to the radiator in the usual way and the return end is open to the atmosphere—in other words, the so-called "open" or "atmos-

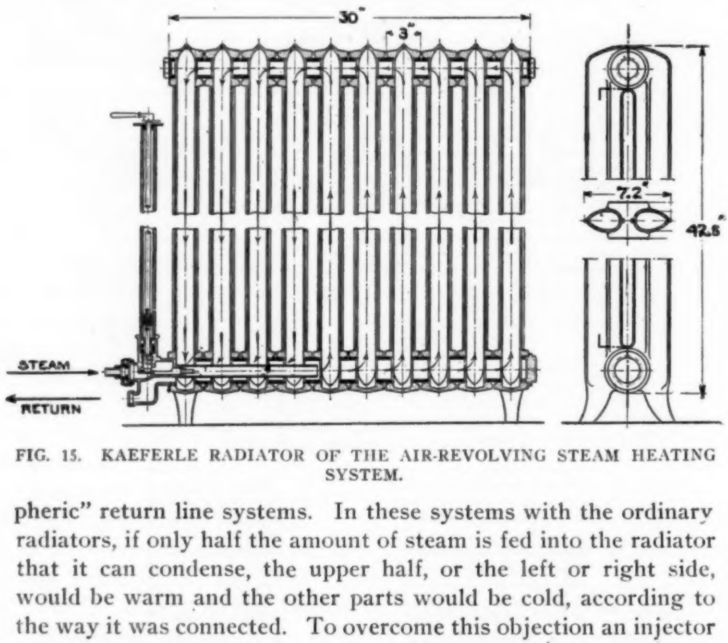



FIG. 15. KAEFERLE RADIATOR OF THE AIR-REVOLVING STEAM HEATING SYSTEM.

pheric" return line systems. In these systems with the ordinary radiators, if only half the amount of steam is fed into the radiator that it can condense, the upper half, or the left or right side, would be warm and the other parts would be cold, according to the way it was connected. To overcome this objection an injector was placed in the radiator as shown in Fig. 15 for the purpose of circulating the air remaining in the radiator when the radiator is only partly filled with steam, securing thus an emulsion of steam and air at a lower temperature. It is a great advance over the ordinary steam heating system, but somewhat extravagant claims were made by the inventors. It was finally tested out and the results of pamphlet No. 9 (45 pages, 11 cuts and 15 tables) may be summarized as follows:

"The interior temperatures, the surface temperature and with it the heating effect of air-circulating steam radiators are greatly dependent upon small pressure regulations.

"The automatic damper regulators used in practice for low pressure steam heating systems show such high unavoidable pressure variations, that a general regulation of the heating effect of the radiators, as is possible in hot water heating systems, cannot be obtained.

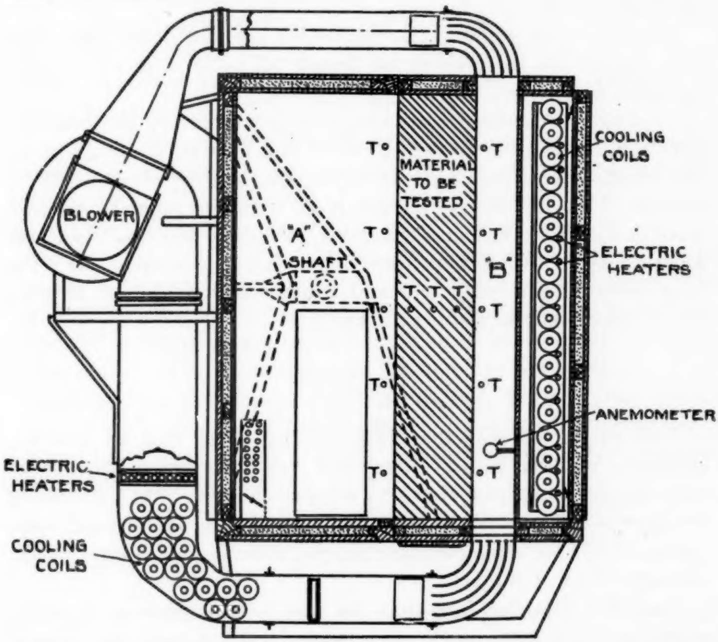



FIG. 16. PROF. BRABBEES METHOD OF TESTING BUILDING MATERIALS, WALLS, DOORS, WINDOWS AND CEILINGS FOR HEAT TRANSMISSION AND AIR LEAKAGE.

"The shutting of a radiator means a higher pressure at the adjoining radiators and creates unavoidable temperature changes in the adjoining radiators so that on account of this fact a regulation for exact and constant surface temperatures for all radiators is impossible.

"In air revolving steam radiators the heat transmission coefficient is not proportional to the temperature, but falls considerably with the growing air mixture."

All of these statements are amply proven in the many tables and cuts published in pamphlet No. 9.

Of course important research work is always being done and the results are awaited with interest by the German heating engineers. One deserves mention, and that is Dr. Brabbee's method of determining heat transmission coefficients, as illustrated in Fig. 16.

It consists of a box ten feet high, ten feet long and five feet wide, which can be turned 90 deg. on shaft "A."

Thus the box may be placed horizontally for ceiling, roof, floor and skylight coefficients.

Ordinary and electric thermometers are profusely placed in and around the material to be tested, so as to observe all temperature conditions.

Cooling and heating coils are provided to create all temperature conditions from 20 deg. C. to 35 deg. C. and finally a blower can create a velocity of air to correspond to the wind velocities outside. The writer is not aware of a more complete method designed so far, that may clear up the many uncertainties still existing as to the corner stone of our heating science, viz.: the heat transmission coefficient and window leakage under varying wind velocities and temperatures.

## CONCLUSION

The writer believes that sufficient has been said so that the members of this Society may well ask themselves whether or not we are doing our share to advance heating and ventilating in theory and practice. Both theory and practice are indispensable, if we in this country are to assume our share in the advancement of the art.

Consider also the fact that the idea of this testing Institute was conceived some twenty-five years ago and only now may it be considered nearly finished.

It took fifteen years to realize the first tangible results. Of course, such an institute does not and cannot dispense with the present shop and laboratory testing and research work of manufacturers, engineering bureaus, commissions, etc. Furthermore, there are many problems that can only be "tested" out in actual practice. On the other hand, there are so many new devices coming on the market which most of the people who are responsible for their installation have neither time nor money to "test" out. Usually the purchaser takes the risk, which very often is detrimental to the whole art of heating and ventilation. It is also realized that the seal of the Institute may well "make" or

"break" the successful sale of any article. For this reason many unworthy articles now coming on the market, would probably be kept off, which no doubt would be welcome to many of us.

But for all, the results of the work of such an institute would be valuable for any one directly interested in the heating and ventilating business. This includes the manufacturer, the contractors and the consulting engineers.

On the other hand, are not the government, state and municipal engineers benefited by having the comparative data on the value of a certain blower, valve, boiler, radiator, pipes, etc.? Hence in turn the government, states and municipalities are benefited by it.

I would like a thorough discussion on the merits of such a similar institution for our country. If the members agree with the writer then the creation of a committee would seem in order. An active campaign extending over several years should be started at once for the purpose of collecting a large sum of money for the building and endowment of such an institution. The large corporations should contribute, because they all have heating and ventilating plants and appliances to operate and maintain and they are interested in having the art advance. Our philanthropists could even be approached, because the proper and cheap provision of healthy heating and ventilation in most of our buildings remains as yet an unsolved problem for the great masses of the people.

## DISCUSSION

A. K. Ohmes: The tests for heat transmission coefficient now being made here will be given out in due time, and the results are awaited by the German heating engineers with great interest. I wish to say that they have one arrangement in Germany that we do not have here, and that is an accepted set of standards of heat transmission coefficients. If an engineer can prove that his surfaces are computed in accordance with the standards, he cannot be sued for damages, because the fault must then be in the building construction.

We have the necessary brains, resources and money, but how long it would take us to get something definite started in this line, if we had the right spirit and energy, I do not know, but probably a good many years. I should like to hear expressions from the members on this. On this occasion I also wish to

acknowledge my thanks and gratitude for much valuable data and plans to Privy-councilors v. Boehmer and Uber and also to Prof. Dr. Brabbee.

A. M. FELDMAN: For the past eighteen months we have become accustomed to learn of the high efficiency of the Germans and the German nation. All of us knew that the German chemical industry is highly developed owing to two reasons: *one*—that every factory of any size maintains a research laboratory in which chemists of the highest rank are leisurely experimenting in order to discover and invent new methods of manufacture and new chemicals; *second*—the German Government maintains a splendid system of industrial schools and continuation schools. In this country we have just began to awaken to the deficiency in progress of the chemical industry, and the governmental bureaus have taken a hold of investigations to advance the industry of dye-making. The Bureau of Mines is doing a great deal in the direction of conducting experiments and disseminating the results.

The first thing that the Naval Consulting Board recommended was the appropriation of $5,000,000 for the establishment of a large experimental plant in conjunction with our upbuilding of the Navy. What the locomotive testing plant at Purdue University has accomplished is well known to the mechanical engineering profession. The cost of the installation of the plant I understand was defrayed by private capital, railroads and locomotive shops.

I am fully in accord with Mr. Ohmes' idea of the value of establishing in this country of a testing laboratory devoted exclusively to the heating and ventilating art, where new appliances could be properly tested out before placing them on the market, and where research work could be conducted for the advancement of the art.

PROF. J. R. ALLEN: I am very much interested in this paper as it is very close to my own work. We have no such elaborate plant, for we have neither the men nor the money necessary to carry on such work. But there is a great demand for this kind of research work.

Many large industrial organizations carry on experiments in their own laboratories, and they are well conducted, but all of them are on materials of some particular concern, and there are many problems of the heating and ventilating profession that do not come within the province of the manufacturer.

The transmission of heat through building materials is a problem of this nature, and the heating and ventilating engineer needs a laboratory where he can study this problem. The Society should consider the subject of having such a laboratory or of allying itself with some laboratory where this work can be carried on.

I am particularly interested in the apparatus which is shown in this paper for testing transmission through building materials. We have similar apparatus at the University of Michigan, and have been working on the subject for about five years. There are many difficulties to overcome, and our apparatus has been changed many times.

We have obtained some results on the transmission of heat through building materials but these have never been published. They give results different from the practice followed by many engineers. But I did not wish to upset transmission standards until I am sure that the results are correct.

The device used at the University of Michigan is box similar to the one described but on trunions. It is located in a room of constant temperature. There is a brine coil running through it and brine is circulated at a low temperature so that a low temperature may be maintained in the box. This sounds easy, but there are a great many difficulties. It took two years to overcome some of them, and we still have some to contend with. The box is on trunions so that the building material can be used as a wall, floor or ceiling. The first experiments have been conducted with glass, using it as floor, wall and ceiling. So far, we have only worked with common glass. This year we are starting with plate glass and later will take other kinds. Our co-efficients that we have determined are higher than is ordinarily assumed. The co-efficient for glass varies from 1.18 to 1.3; the average co-efficient was 1.2. These are the results of our experiments in this line, but these results are subject to correction.

Experiments must be made over long periods of time, and checked frequently to obtain accurate results. There is a wide field of opportunity in this line of work, and accurate experimental data are very much needed by the engineering profession.

James S. Otis: I would suggest that this committee get in touch with the committee that we are going to have on the publication of a text-book, or the work might be given to the same committee, for the subject would be of benefit to all of them. It is

a question that will come before the committee in connection with the publication of a text-book, if it is to be sufficiently authoritative to be considered.

In this country, we have only two places I think where the Society could experiment. One of these is in Pennsylvania, and there you will find perhaps the best arranged building in the United States, if not any country, for conducting experimental work.

A. A. CARY: Some three or four years ago, I spent about a year in various parts of Europe where I became interested in studying the conditions existing there which are referred to in this paper. I had much testing and investigation work to do and I found a spirit of interest existing in Germany, Belgium and France in the line of engineering investigations such as does not exist here. The narrow spirit of commercialism does not seem to have such a predominating hold upon the engineering and manufacturing interests there as it has here. Here, when something new is produced, for instance something in the heating or ventilating line, as soon as it has advanced far enough to be marketable, a company is organized and they then hurriedly proceed to turn out the article as fast as it can be manufactured, by our great American duplicating system. There follows very little change in the product and the only time when a change for betterment is made is when some serious trouble occurs.

I found on the other side that most of the manufacturers have men constantly retained in their establishments perfecting and improving their products. They have young assistants from the technical schools to help them. I had some of these young fellows assist me in my work and I found them more ingenious and interested than the average college graduates you find here. I speak from years of experience as I have had many of the early graduates from our technical schools at work in my office.

In Europe, I found these young men very earnest and applying themselves to their work seriously. There they have a system by which the graduates of a technical institute are obliged to serve an "apprenticeship" for at least a year and they are distributed among the different manufacturing establishments, where they serve without pay. During this time they must prove their ability and worth in order to secure the needed letter of recommendation which is required in order to secure their first job with pay. This first job with pay seldom gives them

more than a small return for their services, but they continue to advance as they prove their worth, a demonstration of which is being constantly demanded.

When I went to Europe I took with me a complete American equipment for boiler testing, and I could not help noting the keen interest shown by my young assistants in every piece of apparatus I had. They were insistent in finding out the details of their construction and the theory of their working.

We talk about America being so far advanced in engineering and manufacturing lines, but unless we get more of the spirit I have described instilled into our manufacturers and our young men, we will soon have to take a back seat. We will soon loose our lead in manufactured products if our manufacturers do not show a greater willingness to constantly improve and make changes in their products and they must also show a greater willingness to encourage investigation and research work as is done in Europe.

To bring about a realization of the necessity of such requirements among our manufacturers is an important field of work for our American engineering societies, and they simply *must* bend their efforts in this direction. All we have to do, to bring this lesson home, is to look at the wonderful and highly efficient producing condition of the countries in Europe, not at war, and we certainly are not in a position to excel the results they have accomplished and it is even open to question whether we could equal these results.

## No. 407

# HEATING AND VENTILATING PLANT OF THE EQUITABLE BUILDING

By W. H. Driscoll, New York

Member

THE Equitable Building, located at 120 Broadway, which has been recently completed, is of such gigantic proportions that the author feels a description of its heating plant should prove of interest to our members.

It is the largest office building in the world and although exceeded in height by several buildings, has never been, and perhaps never will be, exceeded in floor area or cubical contents by any other office building. It is 38 stories in height, not including the two-story pent house. It extends 500 feet above grade, the pent house extending 41 feet additional. The second sub-basement floor is 50 feet below grade.

The building has a total air space in round numbers of 26,000,000 cubic feet and some idea of what this means may be gained from the statement that its cubical contents are about twice that of the Woolworth Building. It is heated by direct radiation with a vacuum return line system, using exhaust steam from the engines, supplemented by live steam passing through a reducing valve.

Seven Heine water tube boilers have been installed aggregating 3,280 H.P. and arranged as shown in Fig. 1. The five boilers that are shown singly are 440 H.P. each and the two boilers set in a battery are 540 H.P. each.

The boilers are hand fired, but provision is made for the future installation of stokers by setting the boilers sufficiently high to accommodate stokers without further change.

Presented at the Annual Meeting of The American Society of Heating and Ventilating Engineers, New York, January, 1916.

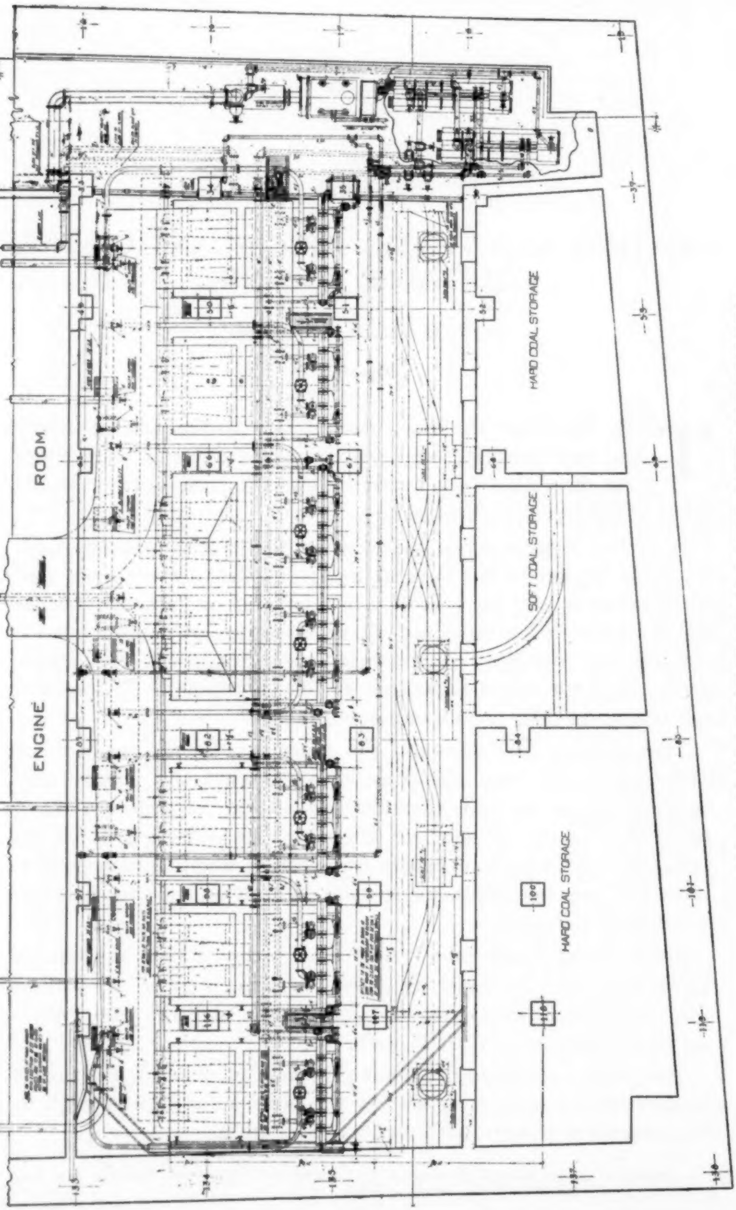



FIG. 1. PLAN OF BOILER ROOM OF THE EQUITABLE BUILDING.

The coal supply is delivered from the street into bunkers located in front of the boilers and chutes leading from the bunkers at convenient points deliver the coal into charging cars which are operated on an industrial track.

The boiler feed pumps, two in number, are located in the boiler room. They are 12 x 18 x 10 x 18 in. in size, of the outside packed plunger type and each pump measures 16 ft. in length. The feed water suction to these pumps connects with a combination feed water heater and meter located on the mezzanine floor above the pump location. The boiler feed water from all sources including the high and low pressure drips, returns from the vacuum pumps of the heating system, the house tanks, water from the ice machine and the Croton water from the street, all pass through this feed water heater and meter. They are not connected directly to this apparatus, however, as the delicate recording instruments of the meter would be affected by an unsteady flow of water into the meter. To overcome this a receiving or air separating tank, 48 x 72 in., is located on the floor above, with outlets connected to all of the sources of supply above mentioned. A constant water level is maintained in this tank by means of a float valve and a 6″ connection is made from the bottom of the tank to the inlet on the feed water heater and this in turn is controlled by a float in the feed water heater, maintaining a constant and steady water line in same.

Duplicate feed lines are installed between the boiler feed pumps and the boilers so that the greatest flexibility of supply is obtained. There are no injectors or other mechanical means of auxiliary feed to the boilers for the reason that in case of emergency the boilers may be fed directly from the house tank located in the pent house under a head sufficient to overcome any possible boiler pressure. Each boiler is equipped with an automatic non-return valve arranged to shut down in case of an accident to any boiler or to the main steam piping. The main header (20″ in diameter) is located on the floor at the rear of the boilers and is divided into four sections by means of gate valves. From this main header connections are taken directly to four of the six engines and a 10″ main starting at one end of the header passes completely around the engine room, connecting into the header at the opposite end, forming a loop, as shown on Fig. 2. This loop supplies steam to the two smaller engines and to the pumps, the pumps being supplied through an 8″ auxiliary loop main. The 10″ main is so valved and dripped that

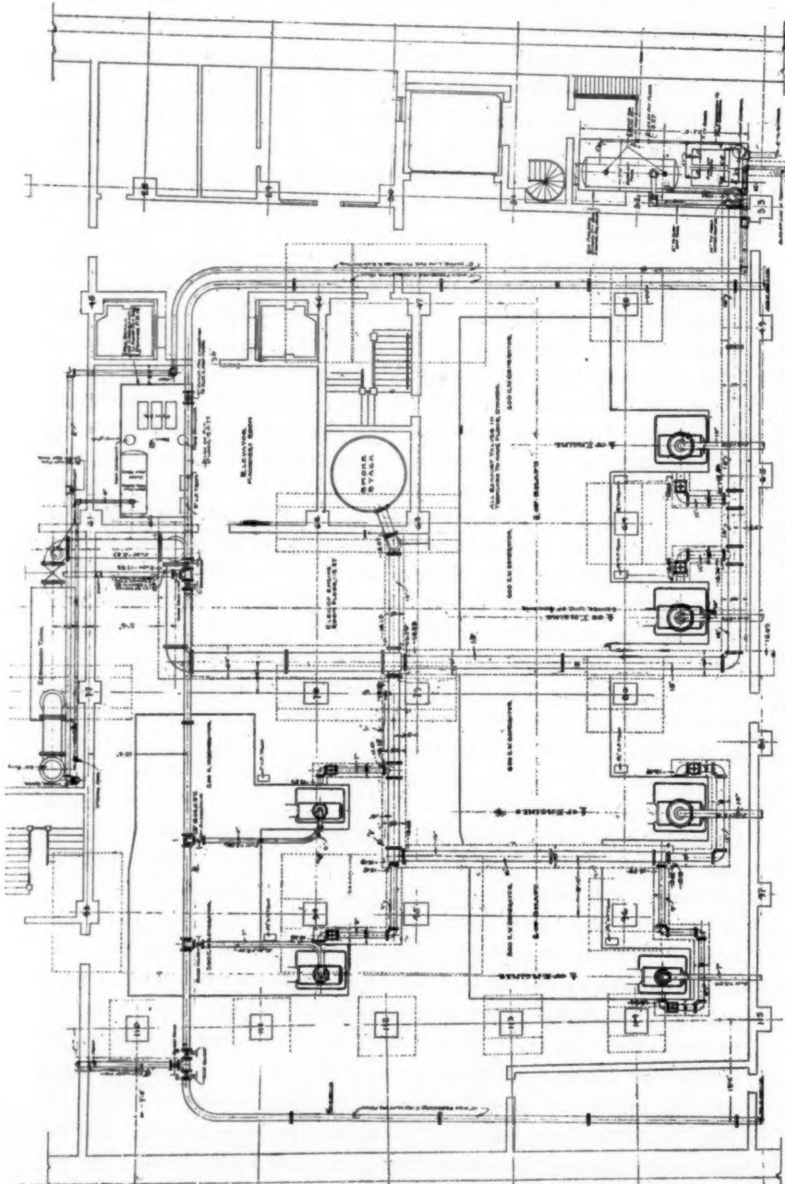


FIG. 2. PLAN OF ENGINE ROOM OF THE EQUITABLE BUILDING.

it can be shut off in sections to provide for necessary repairs without necessitating a shut-down of the plant.

Each engine cylinder is provided with a receiver separator having a capacity three times the capacity of the cylinder of the engine which it supplies.

Bends are used wherever possible and the piping is anchored so that vibration is reduced to a minimum. The exhaust main is run in a trench and is graded toward the pump pit so that the condensation is all taken care of at one low point. This condensation is trapped through duplicate return traps to the dirty drip tank.

The main exhaust pipe is connected to an expansion tank which is a combination muffler and grease extractor 5½ ft. in diameter by 20 ft. long. This tank is not by-passed in accordance with the usual practice but an emergency connection 16″ in diameter is taken from the 30″ main and connected into the base of the smoke stack with a gate valve to same. (The smoke stack is 11½ ft. diameter by 600 ft. high.) It is assumed that any repairs to the grease extractor tank can be made at night when the load is very light and that the 30″ main can be cut out and the exhaust discharged into the stack without any inconvenience resulting.

The pump main is shown on Fig. 3 and in addition to supplying the house pumps, fire pumps, vacuum pumps, air compressors and ice machine it furnishes an auxiliary supply of reduced pressure steam to the hot water heating tanks and to the heating system. The supply to the heating system, however, passes into the expansion tank and muffler, which is used as the source of distribution of low pressure steam to the down-feed and up-feed heating systems, to the fan coils and to the hot water heaters, each of which has a separate connection from the muffler tank.

From the main 30″ outlet on the expansion tank and muffler a connection is taken to the base of the 30″ riser, which resting on a concrete block at the second sub-basement floor extends in a straight line up through the pent house roof where it is capped with an exhaust head 600 feet above its base. Details of construction of this line are shown on Fig. 4.

At the 34th floor there is an outlet left in this riser to which is connected the 24″ heating main for the down-feed system. Above the outlet is a back pressure valve and in order to take up the expansion of the riser up to this point and avoid placing an undue strain on the heating main, an expansion joint

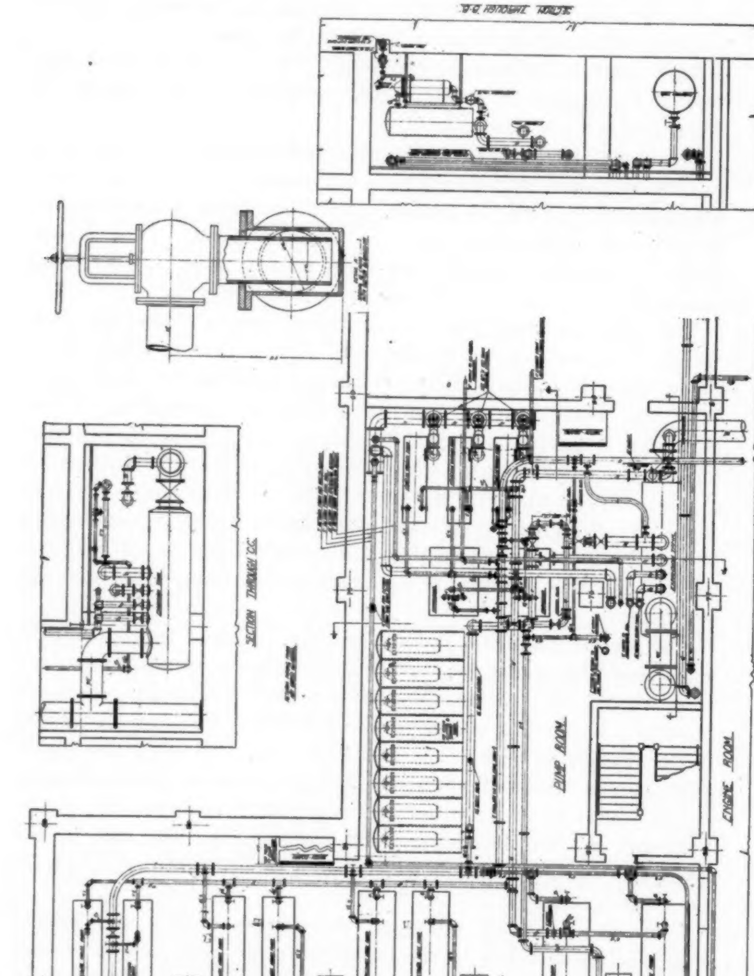



FIG. 3. PLAN OF PUMP ROOM OF THE EQUITABLE BUILDING.

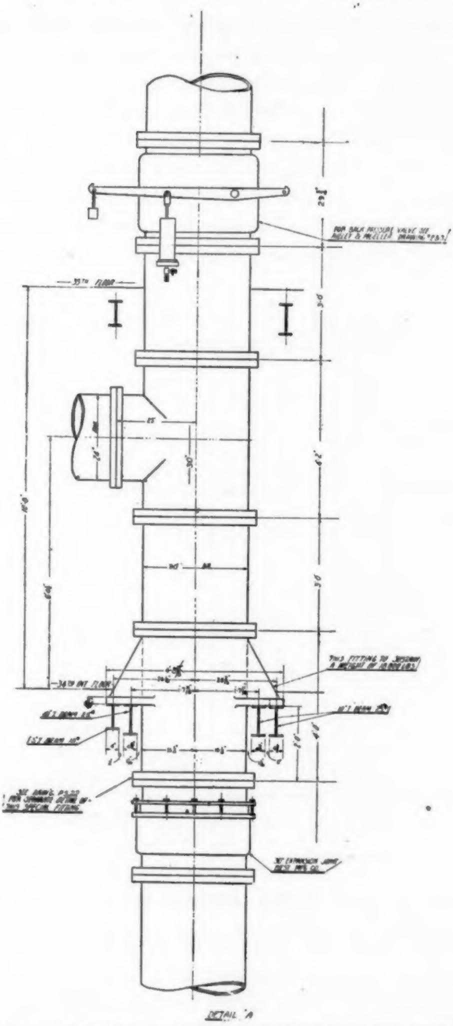


FIG. 4. DETAILS OF EXHAUST MAIN CONNECTION TO HEATING SYSTEM.

is placed in the riser. All of the expansion from the base to the expansion joint is taken up at this point. The weight of the riser above the expansion joint is supported by means of a special fitting resting on the steel construction and bolted to same and all the expansion from this special fitting up goes through the roof.

The condensation from the riser is drained through a 4" loop seal to the clean drip tank with an emergency connection to the dirty drip tank. This loop seal is taken from the tee at the foot of the riser. It might be of some interest to note that this drip tee weighs 5,200 lbs.

The 24 in. main starting at the ceiling of the 34th floor distributes steam to the various risers in the usual manner and presents no unusual features. The floors above the 34th are supplied by short up-feed risers connected to this main and the floors from

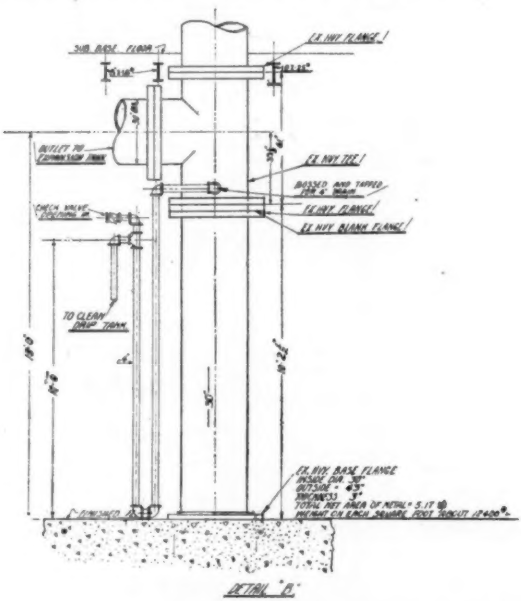


FIG. 4a. SUPPORT OF EXHAUST MAIN AT BASE.

the 2nd to the 34th, are supplied by down-feed risers which generally start at 5 in. in diameter and reduce to a minimum of 2 in. at the bottom. These risers are provided with expansion loops at the 4th, 12th, 20th and 28th floors and are anchored centrally between these floors. The return risers start at ¾ in. in size at the top and increase to a maximum of 2½ in. at the bottom and are provided with similar expansion loops and anchors. A typical expansion loop is shown in Fig. 5.

The radiator branches are all run in the floor fill under the concrete and they are covered with ½ in. covering and further protected by a metal casing, of details as shown in Fig. 6.

Some idea of the immensity of the job may be gained from the fact that in the risers there are 61,000 feet of pipe and 5,000 fittings and in the radiator branches there are 45,000 feet of pipe and 30,000 fittings. There are a total of 5,000 radiators throughout the building aggregating 155,000 sq. ft. of surface.

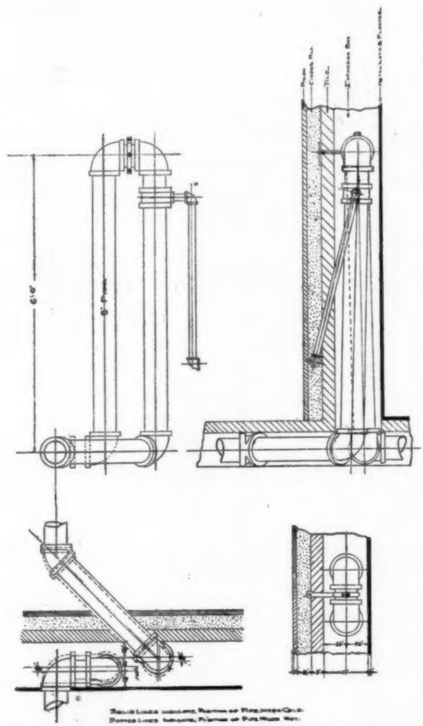


FIG. 5. TYPICAL EXPANSION LOOP IN RISERS.

Most of this radiation is plain surface, single column, 32 in. high and all radiators are located under the windows. Each radiator is provided with a wood wheel packless valve on the supply end and an expansion trap valve or vacuum valve on the return end.

The first floor is heated by means of a separate up-feed system with separate supply and return mains in order that the entire floor may be controlled independently of the balance of the building.

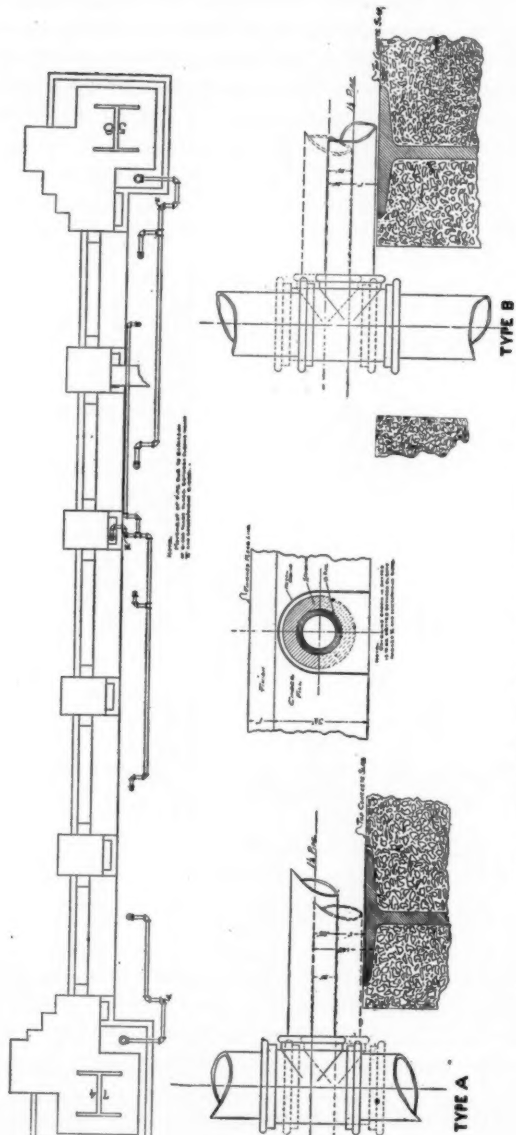



FIG. 6. DETAILS OF BRANCH CONNECTIONS TO RADIATORS.

Separate return mains are run from the down-feed system, the up-feed system, the fan coils and the hot water heaters, and these connect into a 16″ main header located near the vacuum pumps. The vacuum pumps are three in number and 10 x 16 x 16 in. in size, any two of which are of sufficient size to take care of the entire job, maintaining 4 in. to 5 in. vacuum, and any single pump is sufficient in size to take care of the greatest indi-

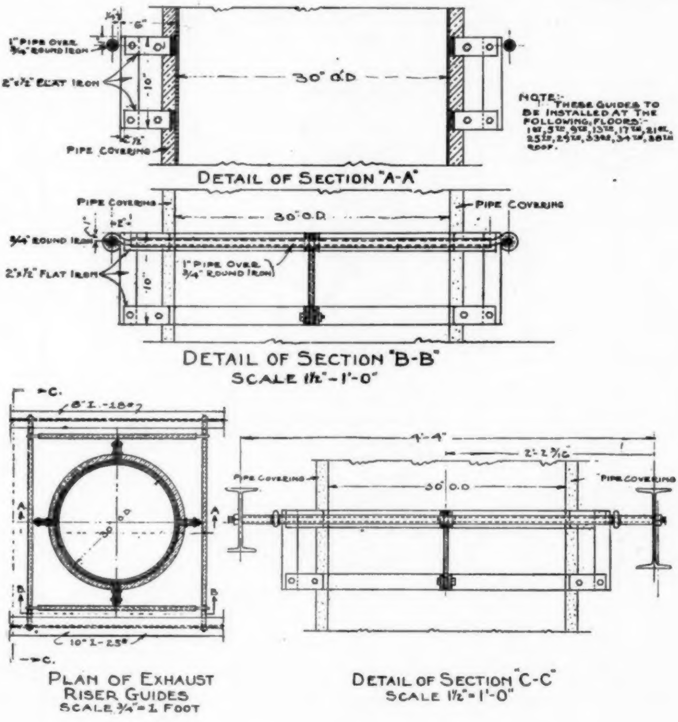



FIG. 7. DETAILS OF EXHAUST RISER GUIDES.

vidual load, which in this case would be the down-feed heating system. The discharge from the vacuum pumps goes direct to the air separating or receiving tank previously described.

For supply and exhaust ventilation and forced blast heating in certain sections of the building there are installed a total of 28 fans. There are 12 supply fans having a total capacity of 278,000 cu. ft. of air per minute. Seven of these fans are used in supplying fresh air for the ventilation of the portions of the

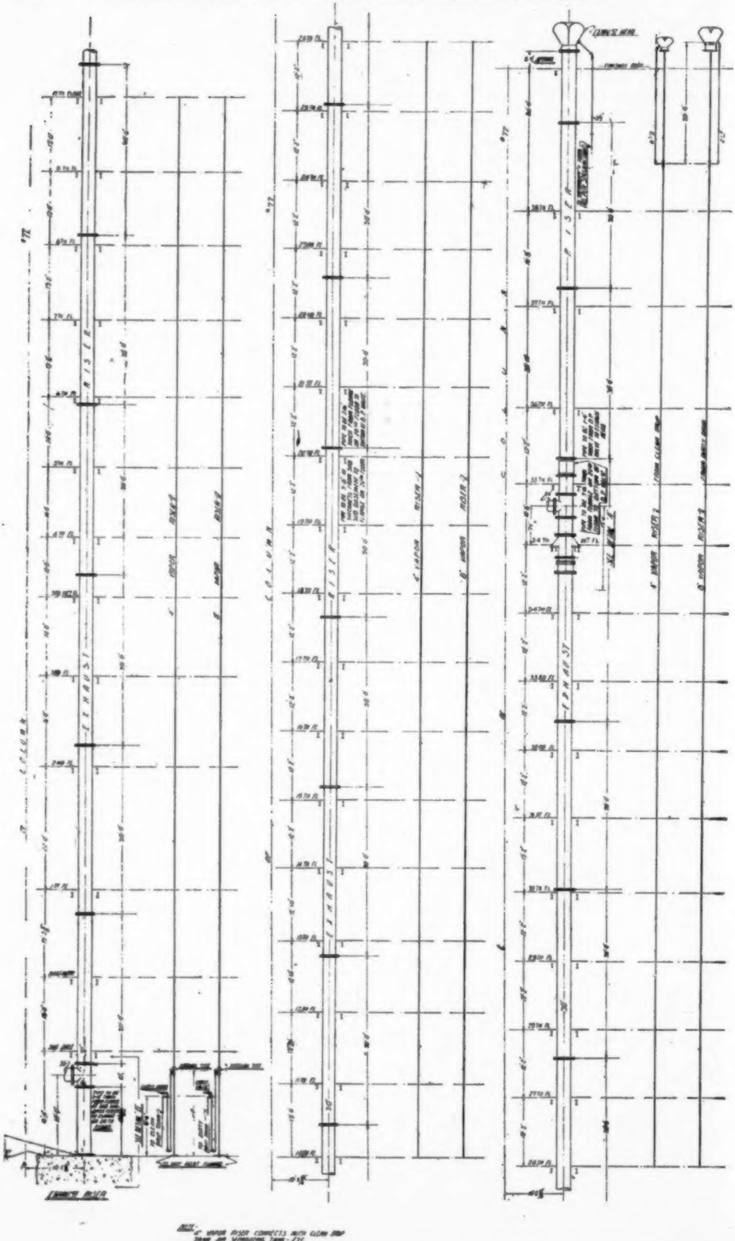


FIG. 8. SCHEDULE OF EXHAUST RISER.

building below grade, which includes the mechanical plant, restaurants, etc.; one is used for supplying air for heating purposes to the main entrances; and four fans are used for supplying fresh air for ventilation to the Bankers' Club, on the 38th floor.

There are 16 exhaust fans exhausting a total volume of 534,000 cubic feet per minute. Seven of these fans exhaust from the mechanical plant, restaurants, etc., below grade, one from the banks on the first floor, one from the offices on the 5th floor, two from all toilets, and five from the Bankers' Club, on the 38th floor.

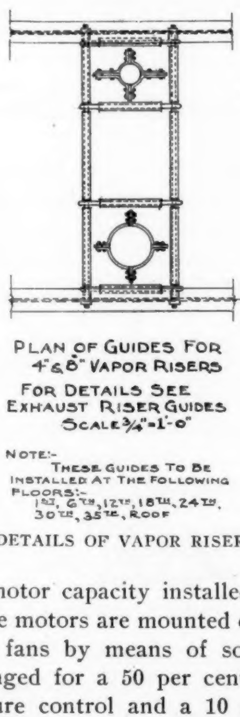



FIG. 9. DETAILS OF VAPOR RISER GUIDES.

There is a total motor capacity installed for operating these fans of 475 H.P. The motors are mounted on steel pedestals and direct connected to fans by means of solid flange couplings. Each motor is arranged for a 50 per cent. reduction in speed by means of armature control and a 10 per cent. increase in speed by means of field control. Separate armature controller and field controller, as well as circuit breaker, for each motor, are mounted on pink Tennessee marble panels, which panels are mounted on angle iron frames resting on the floor.

Cheese cloth filters are furnished in connection with the fans supplying air to the boiler room, engine room, pump room and entrances. These filters are of sufficient area so that the velocity through them will not exceed 40 feet per minute in any case.

The cheese cloth is fastened to wood frames which are erected in angle iron framing in such manner as to be easily removable for cleaning.

In connection with the balance of the supply fans there are installed eight air washers, Acme type, each one of sufficient size that the velocity of air passing through shall not exceed 500 feet per minute. All air washers are made of 18 oz. copper and all piping in connection with same is brass, the pans being made of No. 10 iron lined with 18 oz. copper.

In connection with all supply fans there are furnished cast iron tempering and reheating stacks, all properly proportioned to

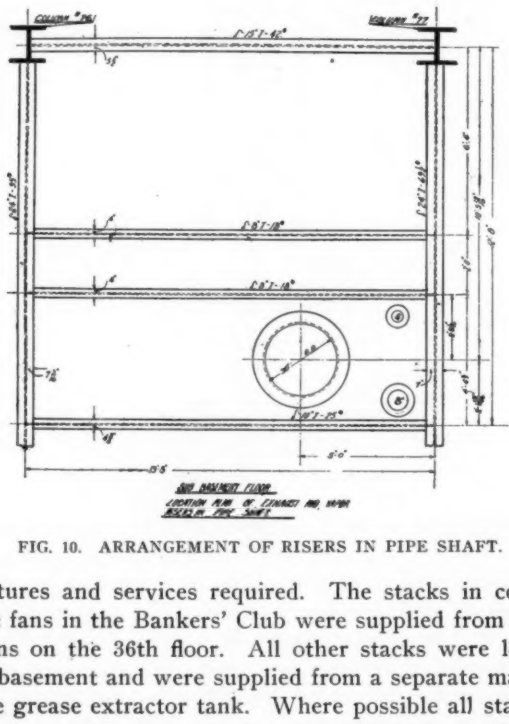


FIG. 10. ARRANGEMENT OF RISERS IN PIPE SHAFT.

temperatures and services required. The stacks in connection with the fans in the Bankers' Club were supplied from the heating mains on the 36th floor. All other stacks were located in the sub-basement and were supplied from a separate main direct from the grease extractor tank. Where possible all stacks were connected up with steam at the top and return at the bottom at opposite ends, with the exception of stacks in which the estimated condensation is in excess of 400 lbs. per hour. In such cases steam connections were made at both ends of the stack at the top with corresponding returns at the bottom and to avoid short circuiting a brass return pipe was extended into the stack from each end towards the center.

All tempering stacks were supported on concrete piers and by-pass dampers were installed under the stacks between the piers, the dampers being controlled by cold air thermostats set in the ducts leading to the stacks. The discharge from the fans is carried to the different sections of the building through individual ducts provided with mixing dampers. The mixing dampers are controlled by room thermostats. There was over 600 tons of sheet metal used in the construction of the ducts.

The job is experiencing its first heating season and there has been no opportunity to secure any data in connection with the cost of operation.

## DISCUSSION

S. R. Lewis: It occurs to me with reference to the installation of these boilers to accommodate stokers at some later date, that I have had two experiences with boilers where extra space was left for the installation of reverberatory arch furnaces. I have not had any tests made, that would demonstrate that their efficiency was increased by setting them in this way, but taking the statements of the people who are operating them, they are getting better efficiency than they were getting with ordinary setting. The boiler has about 2 ft. of extra space and is burning anthracite coal. I wonder if Mr. Driscoll has noticed any increased efficiency in his installation?

M. William Ehrlich: In view of the fact that wind speed and leakage have here been so extensively discussed it might be of interest to know how the radiation was figured, that is, if any special allowance was made for the height and exposure of the building. I understand that the wind velocity increases in some ratio as the height from the ground is increased. The temperature necessarily goes down in some similar proportion accordingly and there is a greater loss through the glass and exposed wall areas at various heights above the ground. Has this variable been taken care of in figuring the size of the radiators?

Wm. J. Baldwin: Mr. Lewis has brought up the question of the height of boilers above the grate bars. I can refer him to an article in the *Sanitary Engineer* (now the *Engineering Record*) in 1883, on this question—an article, with results on boilers, that were operated at various distances from the grates showing the advantages of more height in the furnaces.

I will ask why it is that we take 24 to 36 in. as the accepted distance between the grate and the boiler, and I will answer it by saying I believe the reason is that we have been forced into it by basements and low cellars, and have accepted these conditions.

As a matter of fact, if we can remove the heating surface of the boiler away from the fire, and not lose heat in transmission or by infiltration of air through the furnace wall, we will get better results than we do now; if we can get the boiler away from the flame of the fire so that the combustion will be complete, the results will be better. Recent experiments are in this direction. The matter was known in 1883, but until recently it was not appreciated.

A. A. CARY: Concerning the matter of raising boilers higher than usual, above the grate surface, there has been a growing tendency to do this recently. The best height to place a boiler above the grates depends largely upon the kind of fuel used.

When bituminous coal is delivered upon a fuel bed, its volatile combustible matter is first distilled off and this gas rises and passes into the combustion chamber, while the remaining coke (or fixed carbon) remains behind and burns directly upon the grate surface. The greater the percentage of volatile matter in the coal, the larger the combustion chamber must be. With anthracite coal you do not need as high a setting as with soft coal as its percentage of volatile matter is very low.

There was an installation in the West where I placed the boiler so high above the grate that you could stand upon the grates, under the tubes, and walk around by only stooping slightly. This was a very successful installation, but they use a coal there running almost 40 per cent. in volatile matter. I would not think of using such a setting for anthracite coal. An anthracite coal setting with a height of from 24 to 30 in. above the grates is not necessarily the extreme limit to obtain economical results, as has been commonly supposed.

THE AUTHOR: A definite answer to Mr. Lewis' question would be hard to make at this time. We know the boilers are operating with economy, but whether it is due to the fact that they are high, or whether because the operation is being looked after carefully, we have not determined. I think that possibly within another year or so we can give out something more definite in connection with that.

In answer to Mr. Ehrlich, I would state that a liberal allowance was made to cover leakage. After the building was designed and the radiation laid out, a change was made in the type of window to be used. It was decided to use Winslow windows, the upper and lower sash of which work together and may be swung in and set at different angles. There was a question as to whether additional radiation would be required in view of the use of these windows, and I was asked to investigate and determine, if I could, what the leakage through these windows would be. After some investigation, it was finally decided to add one section to each radiator throughout the building, so as not to take any chances, and this was done. The experiences with the windows, however, have been very satisfactory and the leakage has been only normal, but is influenced to some extent by the conditions on the upper and lower levels.

# No. 408

# HEAT ANALYSIS OF A HOT-AIR FURNACE

By John R. Allen, Ann Arbor, Mich.

Member

THE object of the tests described in this article was to determine the distribution of heat in a hot-air furnace and to find the constant of heat transmission for the heating surfaces.

An average size of hot-air heater of standard make was used in the work. The experiments were made in the Mechanical Laboratory of the University of Michigan.

Below is given data concerning the main dimensions of the furnace:

| | |
|---|---|
| Height | 5′ 0″ |
| Diameter of fire pot | 22″ |
| Depth of fire pot | 16″ |
| Diameter of casing | 48″ |
| Height of casing | 6′ 0″ |
| Grate surface | 2 sq. ft. |
| Heating surface | 69.3 sq. ft. |

The furnace was set up in the basement of the boiler room of the mechanical laboratory. It was erected on a brick setting about 24 in. high and about 8 ft. from the building wall. (See Fig. 1.) The inlet is from below and consists of a 14 x 72 in. vertical galvanized iron flue and an 18 x 24 in. horizontal brick and wood duct. The entrance to the flue is through a 3 x 4 ft. window in the west wall about 9 ft. above the floor.

The outlets from the furnace are two 18 in. diameter pipes with a 5 ft. length slightly pitched and a 6 ft. vertical length. They are placed equidistant from the fire door with an angle of about 130

Presented at the Annual Meeting of The American Society of Heating and Ventilating Engineers, New York, January, 1916.

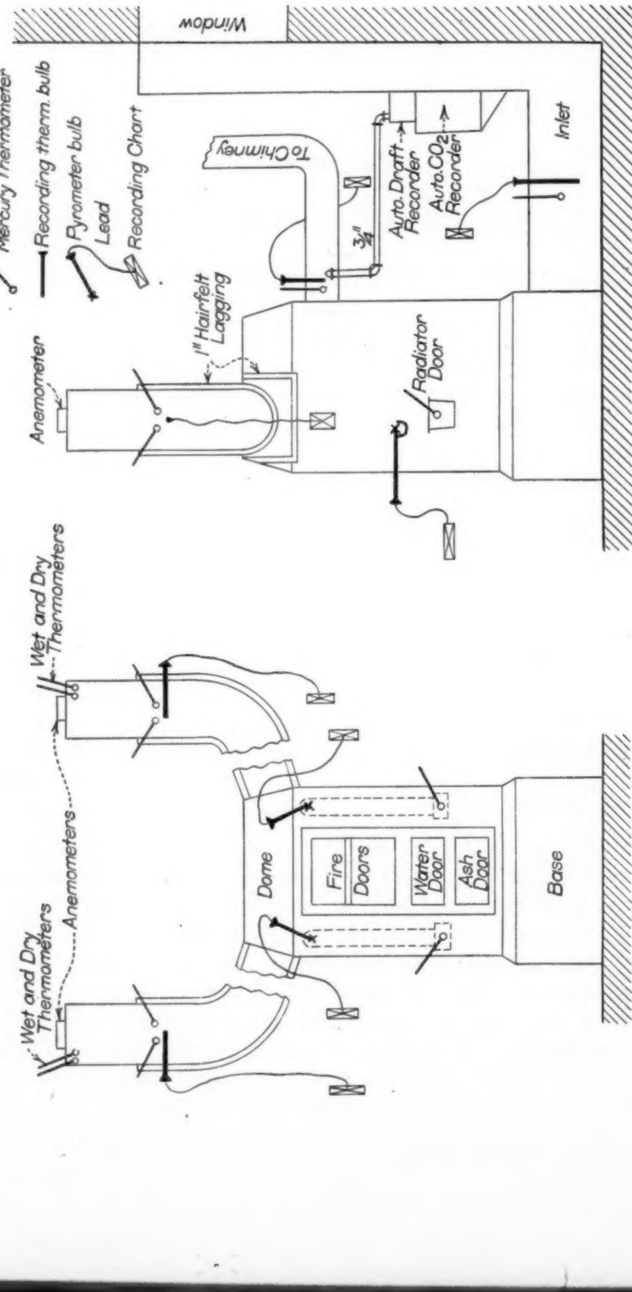



FIG. 1. ARRANGEMENT OF FURNACE AS SET UP FOR TESTING.

degrees between them. The nearly horizontal portion and 3 ft. of the vertical section are lagged with a covering of 1 in. of hair-felt over the customary asbestos paper in order that there would be no loss of heat from the air before it reached the thermometers.

The connection from the breeching to the brick chimney is a 9 in. pipe with a short vertical section and about 20 ft. with a pitch of 1½ ft. in 10 ft. The chimney is about 40 ft. high with the above pipe entering it 10 ft. from the bottom.

Recording thermometers, conveniently placed on the walls were used in measuring the temperature of the inlet air, outlet air, and exhaust gases from the fire. A 1 in. pipe was tapped into the breeching casing and through this gases from the fire were led to an automatic draft recorder and a Simmance-Abody $CO_2$ recorder.

### METHOD OF MEASURING THE QUANTITY OF AIR

Several schemes were tried in the measurements of the outlet air, but the one finally adopted was to use an anemometer in the center of each pipe at the top. These were calibrated in place and under working conditions by means of a pitot tube and slant gauge. The pipe was traversed with the pitot tube in two directions at right angles to each other and ten readings were taken in each direction. The slant gauge was used with gasoline and a 20:1 slant and was calibrated after being used in the tests.

The recording thermometers on the outlet air were calibrated by using mercury thermometers in eight positions in a cross-section of the pipe and taking the average temperature from these. The humidity of the air was found by using a stationary wet and dry bulb thermometer at the exit. In the inlet the recording thermometer was checked with a mercury one. The temperature of the gases over the fire was found with a Hoskins thermo-electric pyrometer having the couple protected from direct radiation by inserting it in the bowl of a porcelain cup well lined with asbestos. Temperature in the top of the flues was found with this pyrometer and in the radiator it was measured with high reading mercury thermometers placed in mercury wells. In the breeching casing the recording thermometer was checked with a mercury thermometer inserted in a mercury well. All the mercury thermometers used were calibrated. The $CO_2$ recorder was checked with an Orsat apparatus and analyses were also made for CO when the $CO_2$ was high, but none was

found. The recording draft gauge was checked by comparison with a stationary gauge. Platform scales were used in the measurement of the weight of the fuel, ash and water.

### THE TESTS

Two series of tests were run. One was with mixed nut and egg anthracite coal as fuel and the other with gas coke. In the first or coal series the plan was to fire the furnace and set the drafts for some definite period. In the second series the furnace was run under the same load, or difference of temperature between the inlet and outlet air, as in the various coal tests and the length of firing period left to come as it might.

### MANNER OF TESTING

In all the tests the start was made with the furnace hot and fire on the grates. An hour or two before the test was to start a fire was built in the furnace and the instruments put in place. At the time of starting the depth of fire and its condition was noted, and at the end of the test the fire was brought back to the same conditions. The refuse for the period was collected from the ash pit and weighed. The water pan always had water in it and was usually filled with ten pounds at a time. Anemommeter readings were taken in general every half hour and about every eight hours the instruments were checked with the pitot tube.

### RESULTS OF THE TESTS

On the following pages are given the results of six successful tests. The data in each column represents a test and the items explaining the figures are given at the left. Item 9 was found from the humidity charts of the American Blower Co.

Item 11 was found from the anemometers.

Item 12 equals item 11, times the area of the two outlet pipes.

Item 13 equals item 12, times density of air.

Item 18 was figured by finding from the ultimate analysis of the coal and the $CO_2$ record, the pounds of air used to burn a pound of fuel. The weight of gas per pound of fuel, times the weight of fuel used per hour divided by 60 gives the weight of gases per minute.

Items 24, 25, 26 and 27 are from analyses of the fuel made by chemists from a sample obtained during the test.

Item 36 equals item 13 times 60 times specific heat times item 35.

Item 37 equals item 33 times heat to evaporate one pound of steam.

Item 38 equals item 36 times item 37.

Item 39 equals item 18 times 60 times specific heat times (item 15 minus item 10).

Item 40 is computed from the weight of refuse drawn minus the theoretical weight of ash from analysis times the heat value per pound of fuel.

Item 41 is computed by finding the areas of the different parts of the casing and assuming a co-efficient of heat transmission for each and multiplying the product of the two above quantities by the difference of temperature between the room and the gas inside the casing.

Item 42 equals item 34 minus item 33 minus item 39 minus item 40 minus item 41.

Item 51 is the net efficiency or the efficiency of the furnace considering only the heat in the air going out of the pipes.

Item 52. The heat from radiation is also useful as far as a house is concerned since it heats up the cellar and keeps the floors warm. The useful or gross efficiency of the furnace is therefore a comparison of the heat which is useful in the house to the heat put in the furnace. It was computed by adding item 46, item 49 and one-half item 50.

Item 58 equals item 57 divided by the product of item 56 and item 53.

## CONCLUSION

The figures in the table are not absolutely correct. In making tests of this kind 5 per cent. of error was considered as about the minimum which could be expected, although all possible corrections were made. This error, which practically cannot be eliminated, is accumulated through many sources, such as air leakage through the casing, probable difference in condition of the fire at the beginning and end of the run, and so forth.

It was found that in order to secure a satisfactory test it must last at least 24 hours. The longer the test and greater the number of firing periods the more accurate are the results, particularly as regards the weight of coal fired. For this reason no test was less than 24 hours' duration and the coke tests were run in one period of 81½ hours.

The humidity as given in the tables is that measured at the outlet of the pipes and is not at all a measure of the humidity in the room heated by the furnace. In the latter case the humidity would be much higher, due to the lower temperature of the air in the room and the moisture in this air. Also the percentage of moisture in the air from the furnace would be higher after the air had cooled in the room since it contains a constant weight of water, but the volume of air would be reduced. It was not possible to measure this humidity in the laboratory because of the large room and the very varying conditions in it.

The measurement of the various temperatures was very difficult because of the possibility of direct radiation from hotter surfaces to the thermometer bulbs. In the final position of the thermometers, however, they were placed so there could be no direct radiation, except perhaps in the case of the pyrometer used to measure the fire gas temperatures. This bulb was protected very well by the cup already described and the error in temperature is probably very small.

It is to be noted that in the tests the water pan always contained water, but this would not necessarily be true in the actual use of the furnace.

The series of tests show that the efficiency of this hot air furnace is high. The combustion is good, equalling that of the modern cast iron steam boiler, and the temperature of the stack gases is not high.

The co-efficient of heat transmission as found from these tests is lower than that obtained in cast iron house heating boilers. This is only an apparent constant as it is impossible to determine the quantity of heat received by the surfaces from the direct radiation of heat from the fire.

In conclusion I wish to acknowledge the assistance of Professor J. E. Emswiler and Wyeth Allen, who conducted the tests and compiled the results.

TABLE 1. DATA OF SIX SUCCESSFUL TESTS.

| | Test No. | 6 | 9 | 7 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|
| 1. | Date | 2/19 & 20 | 3/23 & 24 | 2/22 & 23 | 5/3 & 4 | 5/4 & 5 | 5/5 & 6 |
| 2. | Length of test, hours | 24 | 30 | 30 | 31 | 29 1/6 | 21 1/3 |
| 3. | No. of firings | 3 | 3 | 2 | 4 | 4 | 4 |
| | AIR | | | | | | |
| 4. | Barometer—ins. mercury | 29.57 | 29.07 | 29.11 | 29.3 | 29.1 | 29.21 |
| 5. | Inlet temp., degrees F | 37.7 | 43.0 | 50.6 | 39.6 | 48.0 | 54.4 |
| 6. | Avg. temp. of heated air | 136.1 | 129.2 | 113.7 | 109.2 | 130.4 | 157.4 |
| 7. | Temp. of wet bulb, degrees F | 76.0 | 69.8 | 70.8 | 64.7 | 73.2 | 82.4 |
| 8. | Temp. of dry bulb, degrees F | 134.6 | 127.7 | 112.0 | 107.7 | 128.9 | 155.4 |
| 9. | Humidity, per cent | 7. | 3. | 11.0 | 7. | 4. | 2. |
| 10. | Room temp., degrees F | 77.8 | ....... | 72 | ....... | ....... | ....... |
| 11. | Avg. Veloc. of air delivered, ft. per min | 382.5 | 386.8 | 314.2 | 363.5 | 335 | 350.5 |
| 12. | Volume of air delivered, cu. ft. per min | 1352 | 1367 | 1110 | 1284 | 1183 | 1239 |
| 13. | Weight of air delivered, lb. per min | 89.0 | 89.8 | 74.7 | 87.8 | 77.3 | 77.4 |
| | GASES | | | | | | |
| 14. | Temp. over fire, degrees F | ....... | ....... | ....... | 691 | 777 | 932 |
| 15. | Temp. in breeching, degrees F | 542 | 425 | 309 | 318.4 | 341.6 | 459 |
| 16. | Draft in breeching ins. water | .089 | .090 | .070 | .076 | .076 | .096 |
| 17. | $CO_2$ of gases in breeching, per cent | 13.15 | 10.8 | 10.26 | 8.1 | 9.0 | 10.8 |
| 18. | Weight of gases passing up stack per min. computed from ult. analysis and $CO_2$, lbs | 4.43 | 4.47 | 3.09 | 4.9 | 4.65 | 5.3 |
| | OUTSIDE CONDITIONS | | | | | | |
| 19. | Weather | Clear | Cloudy | Cloudy & Rainy | Clear Rain | Rain | Rain & Cloudy |
| 20. | Wind, miles per hour | 5 from E. | 9 from S.W. | 6 from S.E. | 8 from N. | 5 from S. | 6 from E. |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | FUEL AND ASH | | | | | | |
| 21. | Kind of Fuel | Hard Anthracite | | Mixed Stove & Egg | Gas Coke | | |
| 22. | Total weight of fuel fired, lbs. | 378 | 400 | 255 | 330.5 | 328 | 328 |
| 23. | Total weight of ash and refuse drawn, lbs. | 63.3 | 63.5 | 37 | 16.5 | 15 | 18.5 |
| 24. | Proximate analysis of fuel: | | | | | | |
| | a. Moisture, per cent | .78 | 3.6 | .78 | 6.0 | 6.0 | 6.0 |
| | b. Volatile, per cent | 4.75 | ....... | 4.75 | 3.6 | 3.6 | 3.6 |
| | c. Fixed carbon, per cent | 81.61 | ....... | 88.61 | 86.1 | 86.1 | 86.1 |
| | d. Ash, per cent | 12.86 | ....... | 12.86 | 4.3 | 4.3 | 4.3 |
| 25. | Ultimate analysis of fuel: | | | | | | |
| | a. Moisture, per cent | ....... | .805 | ....... | ....... | ....... | ....... |
| | b. Hydrogen, per cent | 2.56 | 2.25 | 2.56 | ....... | ....... | ....... |
| | c. Oxygen, per cent | 2.79 | ....... | 2.79 | ....... | ....... | ....... |
| | d. Nitrogen, per cent | .90 | ....... | .90 | ....... | ....... | ....... |
| | e. Carbon, per cent | 80.20 | 84.04 | 80.20 | ....... | ....... | ....... |
| | f. Sulphur, per cent | .59 | ....... | .59 | ....... | ....... | ....... |
| | g. Ash, per cent | 12.96 | 8.69 | 12.96 | ....... | ....... | ....... |
| 26. | Heat value per pound as fired, B.t.u. | 12856 | 12759 | 12856 | 13026 | 13026 | 13026 |
| 27. | Heat value per pound of dry fuel, B.t.u. | 12947 | ....... | 12947 | ....... | ....... | ....... |
| | WATER IN PAN | | | | | | |
| 28. | Total water evaporated, lbs. | 107.3 | 114 | 62 | 123 | 122 | 132 |
| | HOURLY QUANTITIES | | | | | | |
| 29. | Weight of air delivered, lbs. | 5340 | 5345 | 4482 | 5270 | 4650 | 4660 |
| 30. | Weight of fuel fired, lbs. | 15.75 | 13.33 | 8.5 | 10.68 | 11.25 | 15.4 |
| 31. | Weight of fuel fired per sq. ft. of grate, lb. | 7.87 | 6.67 | 4.25 | 5.34 | 5.625 | 7.7 |
| 32. | Weight of ash and refuse drawn, lbs. | 2.64 | 2.12 | 1.23 | .533 | .515 | .867 |
| 33. | Weight of water evaporated, lbs. | 4.47 | 3.8 | 2.08 | 3.97 | 4.17 | 6.2 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **HEAT QUANTITIES (HOURLY)** | | | | | | |
| 34. Heat input in fuel, B.t.u. | 202482 | 170077 | 109276 | 138700 | 146700 | 201000 |
| 35. Temp. rise of air, degrees F | 98.4 | 86.2 | 63.1 | 69.6 | 82.4 | 103 |
| 36. Heat absorbed by air B.t.u. | 125000 | 109600 | 67400 | 87400 | 91000 | 114300 |
| 37. Heat given to water B.t.u. | 4880 | 4150 | 2240 | 4300 | 4530 | 6840 |
| 38. Heat given to the air (36 and 37), B.t.u. | 129880 | 113750 | 69640 | 91700 | 95530 | 121140 |
| 39. Heat lost up chimney, B.t.u. | 33700 | 19830 | 12730 | 18720 | 19570 | 31790 |
| 40. Heat lost in unburned fuel, B.t.u. | 7770 | 1240 | 1750 | 970 | 440 | 2620 |
| 41. Heat lost to room by radiation, Bt.u. | 19250 | 15040 | 12020 | 12250 | 14730 | 19050 |
| 42. Heat unaccounted for, B.t.u. | 11900 | 20200 | 13220 | 15040 | 16450 | 26650 |
| **HEAT BALANCE—PER CENT.** | | | | | | |
| 43. Heat input in fuel, per cent | 100 | 100 | 100 | 100 | 100 | 100 |
| 44. Heat absorbed by air, per cent | 61.7 | 64.41 | 61.6 | 63 | 62 | 56.8 |
| 45. Heat given to water, per cent | 2.41 | 2.44 | 2.05 | 3.1 | 3.09 | 3.4 |
| 46. Heat given to air, gross, per cent | 64.11 | 66.85 | 63.65 | 66.1 | 65.09 | 60.2 |
| 47. Heat lost up the stack, per cent | 16.67 | 11.68 | 11.65 | 13.5 | 13.35 | 15.8 |
| 48. Heat lost in unburned fuel, per cent | 3.84 | .73 | 1.6 | .7 | .3 | 1.3 |
| 49. Heat lost to room by radiation, per cent | 9.50 | 8.83 | 11.00 | 8.83 | 10.05 | 9.46 |
| 50. Unaccounted for heat, per cent | 5.88 | 11.91 | 12.10 | 10.87 | 11.21 | 13.24 |
| **EFFICIENCIES** | | | | | | |
| 51. Efficiency—net (46), per cent | 64.11 | 66.83 | 63.65 | 66.1 | 65.09 | 60.2 |
| 52. Efficiency—gross (46 + 49 + ½ of 50) | 76.55 | 81.61 | 80.70 | 80.36 | 80.74 | 76.28 |
| **COEFFICIENT OF HEAT TRANSMISSION** | | | | | | |
| 53. Area of heating surface sq. ft | ...... | ...... | ...... | 69.3 | 69.3 | 69.3 |
| 54. Average gas temp., degrees F | ...... | ...... | ...... | 504 | 559 | 695 |
| 55. Average air temp., degrees F | ...... | ...... | ...... | 75 | 89 | 105 |
| 56. Temp. difference, degrees F | ...... | ...... | ...... | 429 | 470 | 590 |
| 57. B.t.u. per hour transmitted | ...... | ...... | ...... | 87400 | 91000 | 114300 |
| 58. K—coefficient of heat transmission, B.t.u. per sq. ft. of surface per degree diff. of temp | ...... | ...... | ...... | 2.94 | 2.80 | 2.79 |

## DISCUSSION

FRANK K. CHEW: In reading this paper, I found that it gave the amount of air delivered in pounds instead of cubic feet, and that is not what the furnace man wants. The weight of air differs, but using the figures in the table it is readily seen that a cubic foot weights about 15 lb. It would be of value in understanding the paper if a table giving the weight of a cubic foot of air at different temperatures was added.

There were 5,000 lb. of air delivered, or 75,000 cu. ft. If four changes of air per hour are allowed due to leakage, it would be equivalent to a house of about 20,000 cu. ft. of space, which would be a house of about 30 x 35 ft., two stories high.

From the figures given it appears that the furnace used would serve for a house of about 21,000 cu. ft., where the temperature does not fall very low. These figures should have been carried out a little further so that the manufacturers would be able to profit by them. A furnace of 24-inch grate surface and 48-inch casing would suit most people. If the house was very far north or south there would be other conditions, but a furnace of that size would be about right for that amount of work in that climate.

Another thing—these figures are all the results of test conditions. Prof. Willard says that tests of this character do not give the information that the manufacturer needs, and that the proper way of testing a furnace is to pipe it to obtain or duplicate house conditions, which often reduces the effect of the furnace.

Furnaces are mostly used in a class of buildings that many times have neither architect nor engineer, and it is the furnace man's duty to take enough interest in them to have them work right and give the very highest possible efficiency. The Society should give some attention to this method of heating and the class of buildings to which it is especially adapted and try to go further with the work. The majority of the houses that are heated are for those who don't know what it is to have an engineer. Usually the houses are built on speculation and only an inexperienced person goes over them.

I think the ideal heater for small houses costing about $1,500 is a good furnace that will operate efficiently and economically. I have had some experiences with the various methods of heating houses and I know houses of low cost can be satisfactorily heated at a low cost. I know of a place where there were two houses; one was always for rent and the other was always occu-

pied. In one house there were just two ordinary stoves, and in the other there was a furnace, and it didn't take any more coal to heat four rooms with the furnace than it did to heat two with stoves, and the house with the furnace was more comfortable.

J. J. Blackmore: There is an illustration in Prof. Allen's paper that shows how easily one may gain the required amount of humidity when using a furnace such as the one tested. I assume the evaporating pan was placed in the ordinary way inside the door of the ash pit. The quantity of water used and the humidity generated is high, quite a little higher than would be obtained from such a furnace in use in ordinary private houses.

M. William Ehrlich: I agree with Mr. Chew that a table should be given from which can be read either cubic feet or pounds of air. Another suggestion is to have a chart prepared for use as a conversion table. One scale could give the density of 1 cu. ft. of air in pounds and another scale could give the volume of 1 lb. in cubic feet, both varying with the temperature. It is interesting to note from the test figures that the weight of air is about 15 lb. at the working temperature and with a barometer of 29.5 in., whereas the theoretical or accepted tables give the weight of air at sea level at about 13.5 lb. This, of course, is probably due to humidity, dust and other local conditions.

A. A. Cary: I appreciate Prof. Allen's difficulties in endeavoring to obtain correct furnace temperatures. By placing the pyrometer directly over the fire it is affected not only by the hot furnace gases surrounding it but also by the intense heat radiated from the fire bed which causes it to indicate a higher temperature than that actually existing in the furnace. It has not been found to be a simple matter to properly shield the hot junction of a thermoelectric pyrometer from the effects of radiant heat when exposed in a furnace.

The method suggested by Prof. Allen is quite ingenious by using a porcelain teacup but even with this he questions whether he gets the correct temperature, and states that there is need for further correction. The radiation from the highly heated cup itself must be considered.

Where a boiler is operated by furnaces having high temperatures you can use an optical pyrometer to great advantage. I have taken temperature readings from many boiler furnaces and after this long experience, I must confess that I find it

by no means simple to obtain the true temperature readings of such furnaces. This subject needs much study and further careful investigation.

WM. J. BALDWIN: We are indebted to Prof. Allen for this paper. He shows us that in the experiment he was able to get nearly 70 per cent. of the value of the coal into the rooms upstairs. That is under test conditions, of course, but it is an item of interest that is of value to all the members of the Society.

It is true that the majority of our members are not interested in furnace heating, but at the same time it is well for us to know the work a furnace is capable of performing. One of the particular features that we might investigate in furnace heating is how coal can be utilized to a better advantage as many of them are extravagant. I am certain that the efficiency would but rarely be anything like 70 per cent.

ROY E. LYND: This is an excellent paper, in that it demonstrates clearly that a heater of this type is fully as efficient as the steam and hot water heaters generally used for house heating. I have personally conducted many tests on warm air heaters, but have never been able to make as complete a test as that described in this paper, as I have not had all the necessary testing apparatus at my disposal.

One of the interesting points which might be raised in connection with the data given is that an opportunity is afforded for comparing the velocity as found at the outlets with the velocities usually found in regular installations. Referring to the data given under Test No. 6, the density of the air leaving the warm air outlets is equal to

$$d_o = \frac{\text{item } 12}{\text{item } 13} = \frac{89}{1352} = .0659 \text{ lb. per cu. ft.}$$

The total height from the floor to the warm air outlets, as near as the writer can estimate it from the data given, is approximately 16 ft. To arrive at the head producing flow of air through the heater, let us assume that the air from the center of the horizontal cold air inlet, 9 in. above the floor to the bottom of the heater, 2 ft. above the floor, is at the inlet temperature, 37.7 deg. fahr., or 497.7 deg. absolute; the air from the bottom of the heater to the top of the heater, which is 7 ft. above the floor has a temperature which is a mean between the inlet and outlet temperature, 86.9 deg. fahr., or 546.9 deg. absolute; and the air from the top of the heater to the warm air outlets is at the outlet temperature, 136.1 deg. fahr., or 596.1 deg. absolute.

Then the head producing the flow of air is equal to the difference between the weight of this column of air, and the weight of a column of equal height, but at the inlet temperature. We have shown that the density of the air at the outlet temperature is .0659 lb. per cu. ft. The density at the inlet temperature would be

$$d_i = .0659 \text{ x} \frac{596.1}{497.7} = .0790 \text{ lb. per cu. ft.}$$

and the mean density of the air passing through the heater would be

$$d_h = .0659 \text{ x} \frac{596.1}{546.9} = .0718 \text{ lb. per cu. ft.}$$

Then the head producing flow in ounces per sq. in. is equal to

$$P = \frac{(15.25\text{x}.0790) - [(1.25\text{x}.0790) + (5\text{x}.0718) + (9\text{x}.0659)]\text{x}16}{144}$$

$$= .01712 \text{ oz. per sq. in.}$$

The theoretical velocity at the inlet to the heater corresponding to this head is equal to (Fan Engineering, The Buffalo Forge Co.),

$$V_i = 1444.5 \sqrt{\frac{P}{W}}$$

in which $V_i$ = velocity at inlet in ft. per min.
$P$ = head in oz. per sq. in.
$W$ = density of air at inlet temperature.

Then we have

$$V_i = 1444.5 \sqrt{\frac{0.01712}{0.0790}}$$

$$= 672 \text{ ft. per min.}$$

Then the theoretical outlet velocity would be equal to

$$V_o = 672 \text{ x} \frac{596.1}{497.7} \text{ x} \frac{3.00}{3.53}$$

$$= 684 \text{ ft. per min.}$$

In the above derivation of the value of $V_o$, $\frac{596.1}{497.7}$ = the ratio of absolute temperatures at outlet and inlet, and $\frac{3.00}{3.53}$ = the ratio between inlet and outlet areas.

The actual outlet velocity, as indicated in item 11 was 382.5 ft. per min., or $\frac{382.5}{684}$ = 55.9 per cent. of the theoretical. In

heating installations where all the air is taken from outdoors and no vent flues are provided, and a relatively high static pressure is set up in the heated rooms, it is safe to assume that one-third of the theoretical velocity will maintain in the warm air pipes. In re-circulating systems, where relatively little static pressure is set up in the heated rooms, the actual velocity will run as high as half of the theoretical. The high velocity ratio obtained in these tests was due, no doubt, to the very large inlet window and vertical cold air box, and to the fact that the two large warm air pipes had very much less resistance than the usual six or eight small pipes of about the same area, which would generally be used. Also in practice we have registers over the outlets, and usually rectangular risers to the upper floors, both of which items materially increase the resistance.

It is also interesting to note the relation between the static head representing the loss in pressure of the air passing through the heater, due to friction, change of velocity, change of direction, etc., and the velocity head, or the head necessary to produce the velocity in Test No. 6 was 382.5 ft. per min. The actual inlet velocity would then be

$$V_i = 382.5 \times \frac{497.7}{596.1} \times \frac{3.53}{3.00}$$

$$= 376 \text{ ft. per min.}$$

The velocity head corresponding to this is equal to

$$P_v = W \left(\frac{V_i}{1444.5}\right)^2$$

the symbols used being the same as the case where another form of the same formula is used above.

Then we have

$$P_v = .0790 \quad \frac{376}{1444.5}\Big)^2$$

$$= .00535 \text{ oz. per sq. in.}$$

The total head, we have shown above, is

$$P_t = .01712$$

Then the static head is equal to

$$P_s = P_t - P_v = .01177 \text{ oz. per sq. in.}$$

or 2.2 velocity heads.

It is to be regretted that no more accurate method of measuring velocities was available than the anemometer, which is an unreliable instrument at best. It has occurred to the writer that such tests as those made by Mr. Allen could be made a little more accurate by feeding the air to the heater by means of a

fan and a small duct connecting with the casing of the heater by means of a diverging nozzle, the whole apparatus being so proportioned that the same velocity of air could be maintained at the warm air outlets, and at the same time a relatively high velocity could be maintained in the duct leading from the fan. The air velocity in the supply duct could then be measured by means of a pitot tube, a venturi meter, an orifice, or a Thompson electric meter. It seems to me that more accurate determinations of the quantity of air flowing through the heater could be made in this way.

Another point deserving of comment in connection with these tests is the determination of the values of K, as shown in item 58. I do not believe Mr. Allen's figure is correct, as he assumes that the average gas temperature, in Test No. 11 for example, is 504 deg. Now this is all right for the gases only, but about three-quarters of the heat transmitted by the heating surface, as I shall show, is transmitted by the surface of the fire-pot, the fire in which is at a much higher temperature than 504 deg. Also the heat transmitted by the heating surfaces is not item 36, as Mr. Allen gives it, but item 36 + item 41 + ½ item 42. Let us investigate this question.

The weight of gases per hour, referring always to Test No. 11, is:

$$\begin{aligned} G &= 60 \text{ x item } 18 \\ &= 60 \text{ x } 4.9 \\ &= 294 \text{ lb. per hour.} \end{aligned}$$

The temperature over the fire (item 14) is given as 691 deg. fahr. It seems safe to assume that combustion is practically complete when this temperature is reached. The flue temperature (item 15) is given as 318.4 deg. fahr. Then the heat transmitted by the heating surfaces above the fire is equal to

$$\begin{aligned} H_g &= 294 \text{ x } (691 - 318.4) \text{ x } .2375 \\ &= 26000 \text{ B.t.u. per hour.} \end{aligned}$$

The total heat transmitted by all the heating surfaces amounts to

$$\begin{aligned} H_t &= \text{item } 38 + \text{item } 41 + \tfrac{1}{2} \text{ item } 42 \\ &= 111470 \text{ B.t.u. per hour.} \end{aligned}$$

The heat transmitted by the fire-pot surface is therefore

$$H_f = H_t - H_g = 85470.$$

The firepot surface therefore transmits $\frac{85470}{111470}$ or 76.7 per cent.

of the total, and the heating surface other than the firepot transmits $\frac{26000}{111470}$ or 23.3 per cent. of the total. Now the firepot is 22 inches in diameter at the top, 19.17 inches in diameter at the bottom, and 16 inches deep, and has approximately 8 sq. ft. of heating surface. The total heating surface is given as 96.3 sq. ft. Therefore the heating surface, other than the firepot, amounts to 61.3 sq. ft.

The heat transmitted by the firepot per sq. ft. per hour, therefore, amounts to $\frac{85470}{8}$, or 10684 B.t.u. per sq. ft. per hour, and by the heating surface other than the firepot, $\frac{26000}{61.3}$, or 424 B.t.u. per sq. ft. per hour. Now to get the average temperature of the air outside of the firepot, it is necessary for us to assume that all the heat from the firepot which is absorbed by the air is utilized in raising the temperature of the air to some temperature, and that none of the heat from the other heating surface is absorbed by the air until after that temperature is reached. After that temperature is reached, all of the heat absorbed by the air from the surfaces above the firepot is utilized in bringing the air up to the outlet temperature. This is equivalent to saying that the firepot is assumed to do its work alone first, and then the other surfaces alone do their work.

The total amount of heat given out per hour by all the heating surfaces is 111470 B.t.u., but only 87400 B.t.u. are utilized in raising the temperature of the air. Therefore the portion of the heat given off per hour by the firepot, which is utilized in raising the temperature of the air, is $\frac{87400}{111470} \times 85470$, or 67000 B.t.u., and the amount of heat transmitted per hour by the other surfaces, which is utilized in raising the temperature of the air is $87400 - 67000 = 20400$ B.t.u. The temperature rise due to the heat from the firepot is then

$$\frac{67000}{60 \times 87.8 \times .2375} = 53.5 \text{ deg.}$$

and the temperature of the air after it has received all the heat from the firepot is $39.6 + 53.5 = 93.1$ deg.

Now, considering first the surface above the firepot; the mean temperature of the air outside this surface is

$$93.1 + \frac{109.2 - 93.1}{2} = 101.1 \text{ deg.}$$

The mean temperature of the gases inside this surface is

$$318.4 + \frac{691. - 318.4}{2} = 504.7 \text{ deg.}$$

The value of the co-efficient for this part of the surface is then

$$K = \frac{424}{504.7 - 101.1}$$
$$= 1.05$$

The theoretical elevation of temperature of the fire, according to Kent, is equal to the quotient obtained by dividing the heat produced by the combustion in any unit of time by the product of the weight of gases produced in the same time multiplied by the specific heat of the gases. Therefore the elevation of temperature is equal to

$\frac{138700}{294 \times .2375} = 1986$ deg. above the temperature of the air in the room.

The theoretical temperature of the fire is then $t_f = 1986 + 74 = 2060$ deg. fahr. approximately.

The mean temperature outside the firepot is

$$39.6 + \frac{101.1 - 39.6}{2} = 70.4$$

Then the value of K for the firepot is equal to

$$K = \frac{10684}{2060 - 70.4}$$
$$= 5.37$$

This value of K for the firepot surface is based on the assumption that the fire has the maximum theoretical temperature. The temperature of the fire appears in the denominator of the above expression so that any reduction in the fire temperature would produce a correspondingly higher value for K. Therefore, as the temperature of the fire is undoubtedly less than the theoretical, it is safe to say that the value of K given for the firepot surface will be less than the actual K for the same surface. In other words, K for the firepot surface will actually be greater than 5.37.

THE AUTHOR: Of course, I must admit the inadequacy of these tests, in regard to actual house conditions, but it is almost impossible to test a furnace under such conditions. The complication of apparatus would be so great and the number of men required so large as to be prohibitive.

More water was used in the water pan than would be used in the average residence. The water pan was filled every

hour, which goes to show that to properly humidify the air in a furnace it is necessary to have the water supplied to the water pan automatically.

The question of determining the temperatures of the hot gases in the furnace involves many difficulties, and in any furnace can only be an approximation. Even after the temperature of the air in the furnace is obtained this is not the temperature of the inside surfaces of the furnace, as these surfaces receive some radiant heat directly from the fire. I have tried to obtain the temperature of the inside of the hot surface in the furnace in many different ways, but I am not satisfied with the results. I hope some good methods will be worked out for the solving of this problem.

The furnace was operated as nearly as possible under ordinary conditions of firing at about 8-hour periods. The furnace used was new and tight, and no doubt gave better results than would be obtained with a furnace after it has been in operation for some time. But the conditions could probably be duplicated in a furnace operated with very good attendance under house conditions.

No. 409

# THE PREVENTION OF CORROSION IN PIPE

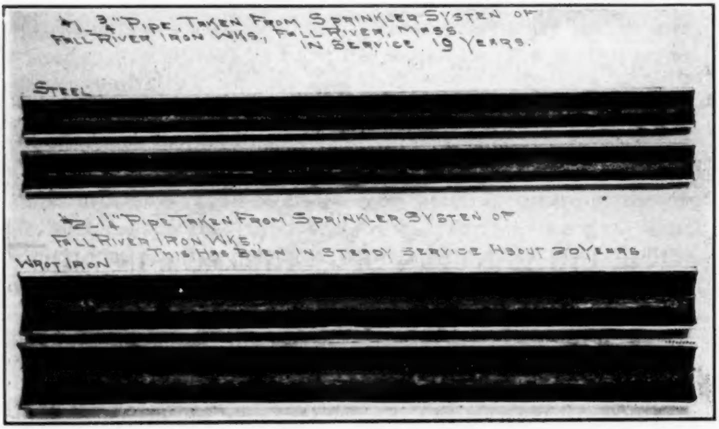
By F. N. Speller, Pittsburgh, Pa.

Member

CASUAL observation will show very marked differences in the degree of corrosion of pipe in service. For instance, hot water heating systems and sprinkler systems show practically no deterioration in service after twenty-five years, while low pressure steam returns sometimes give trouble after fifteen years' service or less. Galvanized pipe in hot water supply systems, where the water is heated under pressure, lasts from about five years upwards, depending on the temperature and quality of the water and volume of flow. The last named condition is so severe on iron and steel pipe that many are compelled to use brass pipe, at a cost approximately ten times that of galvanized pipe. These few instances are the extremes, but are surely suggestive when we consider that in pipe carrying ordinary water under some conditions there is no apparent deterioration in a generation; whereas in other cases, the same grade of pipe is seriously damaged in a very few years. A few illustrations of the present condition of old sprinkler lines after long service are shown in Fig. 1 and Fig. 2.

Some years ago, when steel pipe was comparatively unknown and not fully developed, it was natural to question this material, but comparisons of the modern wrought iron and steel pipe in the same lines in service have shown beyond any question that where corrosion is found one material suffers on the average as much as the other. Some references to practical comparisons of the life of various wrought pipe carrying water will be found in a paper by L. C. Wilson entitled "Wrought Iron or Steel

Presented at the Annual Meeting of The American Society of Heating and Ventilating Engineers, New York, January, 1916.



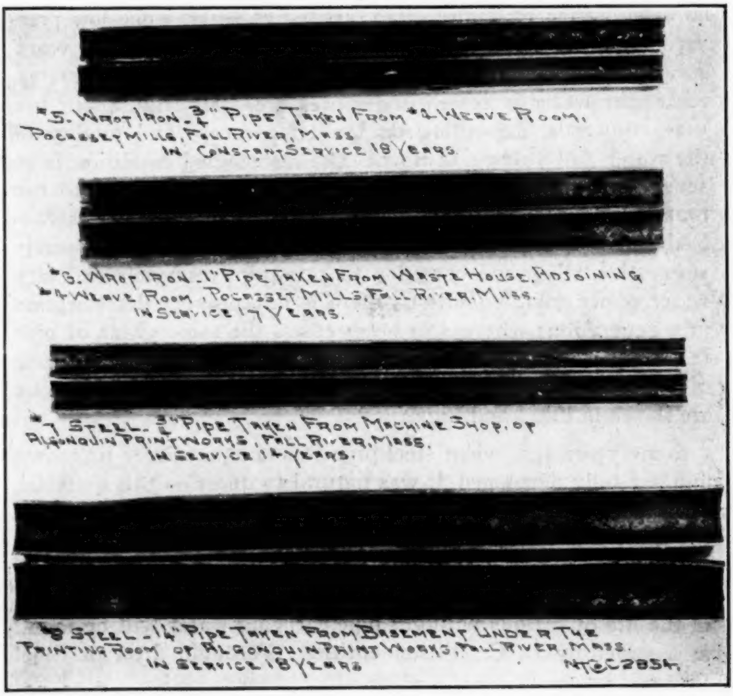




FIG. 1. SECTIONS OF SPRINKLER PIPES AFTER YEARS OF SERVICE.

Pipes?" in *The Engineering Magazine* for November, 1915.

It has been the custom of the writer to keep several service tests under way continuously for the past few years. In every case the co-operation of some local engineer or organization is sought under whose immediate direction the test is conducted. One of the most recent to be completed may be described as an example of the method pursued in conducting such tests. This test was made in the Pennsylvania Building, Philadelphia, Pa., by Mr. Munsey, engineer. Four standard grades of pipe of

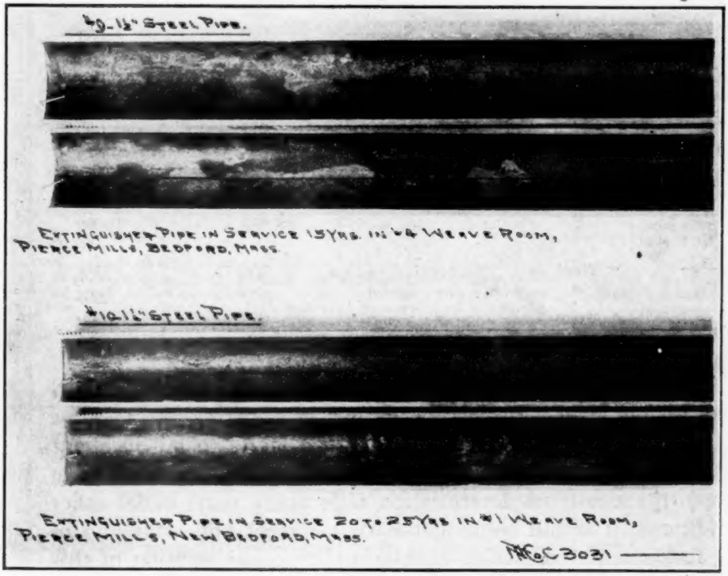



FIG. 2. SECTIONS OF SPRINKLER PIPES AFTER YEARS OF SERVICE.

well known manufacture were selected and four pieces of each taken at random and coupled together alternately so that the hot water passed through each sample at the same temperature.

### DETAILS OF TESTS

Date installed—October 27, 1913.

Date removed—November 20, 1915.

Location—Hot water return line, Pennsylvania Building, Philadelphia.

Temperature of water—175 degrees Fahrenheit average.

Amount of water—5,000 gallons per day for 600 days.

Method of installation—In form of box coil.

TABLE 1. CORROSION MEASUREMENTS

| Lot | Material | Sample Number | Depth of pitting in inches: Average of 10 deepest pits in each piece | Depth of pitting in inches: Deepest Pit |
|---|---|---|---|---|
| A | Steel | 1 | .068 | .094 |
| " | " | 2 | .087 | .124 |
| " | " | 3 | .045 | .050 |
| " | " | 4 | .063 | .074 |
| B | Steel | 5 | .079 | .104 |
| " | " | 6 | .056 | .094 |
| " | " | 7 | .054 | .065 |
| " | " | 8 | .070 | .081 |
| C | Iron | 9 | .065 | .073 |
| " | " | 10 | .072 | .097 |
| " | " | 11 | .078 | .105 |
| " | " | 12 | .077 | .080 |
| D | Iron | 13 | .055 | .075 |
| " | " | 14 | .067 | .112 |
| " | " | 15 | .067 | .078 |
| " | " | 16 | .073 | .090 |
| | | | | |
| A | Steel | General Average | .066 | .085 |
| B | " | " " | .067 | .086 |
| C | Iron | " " | .073 | .089 |
| D | " | " " | .066 | .088 |

A resume of a large number of these service tests compiled from several sources is given in Table 2.

Inasmuch as both materials have been found to fail in about the same time under the same conditions, and as both have shown practically no deterioration after many years under other conditions, it would seem that with a correct understanding of the fundamental causes of corrosion a practical solution of this problem should be possible. The author has devoted a considerable portion of his time for the past ten years to a study of the factors governing corrosion of pipe in service, and is writing this paper in order to open up a more general discussion of preventative measures.

The inside of pipe is subject to peculiar conditions not to be compared with external corrosion, and the inside surface is particularly vulnerable in that protective coatings are difficult to apply, therefore more liable to be defective.

Consider for a moment the situation in a hot water heating system and a hot water supply system where the temperature of the water is about the same. It is evident that the water alone is not responsible for the results observed, but rather something brought in with the water. The hot water heating

TABLE 2

**SUMMARY OF RESULTS OF INVESTIGATIONS OF THE CORROSION OF IRON AND STEEL IN ACTUAL SERVICE**

| No. | Date | Locality | Length of Time Pipe Lines Were Installed | Character of Service | Authority | Number of Cases on Record | Average of Deepest Pits: Wrought Iron | Average of Deepest Pits: Steel | References for Details and Remarks |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1910 | New York City bath-houses. | 3 yrs. and over | Hot water supply service. | Prof. Ira H. Woolson, Columbia University. | 89 samples secured, of which 17 are wrought iron and the remainder steel. | EQUAL 100% | 100% | Eng. News, Dec. 3, 1910, p. 630; N. T. C. Bulletin No. 2. This was a test of iron and steel pipe in actual service continued to destruction. |
| 2 | 1910 | Frick Coke Co. power plants. | 6 mos. to 7½–8 yrs., varying with the comparisons secured. | Boiler feed water lines. | Research Laboratory National Tube Co. | 21 lots comprising 52 samples, of which 26 are iron and 26 steel. | .112" 100% | .108"* 96%* | Eng. Review, April, 1911; N. T. C. Bulletin No 3; Amer. Soc. Heating & Ventilating Engrs., 1911. Pipe samples secured from lines in actual use. In 22 cases of adjacent iron and steel pipes in same lines, 13 comparisons favor steel and 9 iron. |
| 3 | 1911 | Cresson (Pa.) coal fields. | 6 mos. to 10 yrs., varying with the comparisons secured. | Hot and cold water boiler feed lines; pump discharge lines. | Research Laboratory National Tube Co. | 9 comparisons of iron and steel found together. | .100" 100% | .085"* 85%* | Pipe samples secured from lines in actual use. In 9 cases of adjacent iron and steel pipes found in same lines, 4 comparisons favor steel and 2 iron; in 3 cases the steel and iron are equally corroded. |
| 4 | 1911 | Allegheny General Hospital. | Between 7 and 8 years. | Hot water supply service. | Research Laboratory National Tube Co. | 69 samples from hot water lines, 42 wrought iron and 27 steel. | .105" 100% | .105"* 100%* | Conditions those of actual service, and pipe was tested to destruction. In 13 cases of adjacent iron and steel pipes found in same lines, 7 cases favor steel and 6 iron. |
| 5 | 1911 | New England Investigation. | 2 yrs. to 17 yrs., varying with the comparisons secured. Average 9 yrs. | Hot and cold water, live and exhaust steam, brine, boiler blow off lines, etc. | Dr. W. H. Walker, Director Research Laboratory of Applied Chemistry, Massachusetts Institute of Technology. | 54 comparisons of iron and steel found together, in hot water and steam lines. | .069" 100% | .063"* 91%* | Eng. News, Dec. 21, 1911; Jour. of New England Water Wks. Assn. Jan., 1912. Actual service conditions. In 54 cases of adjacent iron and steel pipes found in same line, 20 favor steel and 18 iron, 9 show no difference in corrosion and 7 no corrosion at all. |
| 6 | 1913 | New York City Hotel Investigation. | 6 to 10 years. | Hot water supply and steam return lines. | Dr Wm. Campbell, Columbia University, co-operating with Research Laboratory N. T. Co. | From 60 samples 9 comparisons of iron and steel were found | .095" 100% | .067"* 70.5% | Conditions those of actual service, pipe used to destruction. The iron samples failed in 20 spots; the steel failed in 2 places; due to pitting. |

NOTE—Depth of pitting in wrought iron samples considered as 100% in all cases.

*Calculated from the deepest pit in each sample.

lines have started to rust and then the action has apparently stopped, while in hot water supply lines the action is continuous and rapid: so much so, that if the pipe does not fail by leaking it may be plugged up tight with the reddish hydroxide of iron. The only way to account for this accumulation of oxide of iron is through the oxygen in solution in the cold feed water, amounting to 6 to 10 cubic centimeters per liter according to the temperature and quality of the water. This very small percentage of oxygen is apparently the measure of the destructive power of the water and accounts for the fact that a limited volume of water has no serious action on iron, whereas when this water is renewed continually, especially when heated, the results are liable to be most disastrous. It will be useful to consider the mechanism of corrosion before discussing ways and means for preventing this action.

All water supplies carry more or less foreign matter in solution. What are usually considered the purest natural water supplies are generally saturated with oxygen and carbonic acid, which cause such waters to be very corrosive particularly when heated. Iron in all its forms is soluble in water to the amount of a few parts per million, depending on its composition and that of the water. In this treatise, in referring to water in connection with corrosion, it will be understood to include domestic supplies of the usual degree of purity. Chemically pure water does not occur in nature, and therefore may be omitted from consideration.

The phenomenon of solution is now generally explained as an electrochemical reaction. When pieces of zinc and copper are connected together and suspended in water, a current of electricity starts to flow through the water from the zinc to the copper. The zinc is termed the anode and the copper the cathode. While the current flows the zinc goes into solution, the amount dissolved being proportional to the current according to Faraday's Law.

If we replace the zinc with a piece of iron, a current flows in the same direction and iron will be found in solution. Suppose we now replace the copper with another piece of iron. A small current of electricity will still flow, but not necessarily in the same direction, this depending upon the relative surface condition of the two pieces of iron.

It is this small current flowing between one piece of iron and another under water which causes iron to enter solution, and this is now recognized as the *initial reaction of corrosion*. Solu-

tion is hastened by carbonic acid and mineral salts in solution, as these make the water a better electrolyte. However, it has been proved that iron will dissolve to some extent in the purest water that has yet been made. If the iron is exposed to nothing but water this reaction will soon cease, due to the accumulation of hydrogen at the cathode causing polarization; and this is what actually happens in practice in hot water heating and other systems in which the water and consequently the supply of free oxygen is not renewed. On the other hand, when oxygen is present it combines with the hydrogen, depolarizing the surface of the iron and thus causing solution of the iron to continue. Oxygen enters further into the reaction by combining with the ferrous hydroxide to form insoluble ferric hydroxide, generally known as rust. With an unlimited supply of water and oxygen, corrosion will continue until the iron is all converted into the form of ferric hydroxide.

So far most of the authorities are agreed as to the cause of corrosion, although there has been considerable scientific argument as to whether a trace of carbonic acid ($CO_2$) is necessary or not for the solution of iron. For all practical purposes we can let this question rest and combine the acid and electrolytic theories into one, as outlined above, which affords the best explanation of the observed facts available at this time.

Ever since the electrochemical theory of corrosion was proposed by Whitney in 1903 there has been a division of opinion as to the cause of the difference of potential observed between two pieces of iron. The majority at first assumed that this was due to variation in composition of the metal, and the manufacture of iron of a high degree of purity in the open hearth furnace was heralded with great expectations as to durability. So far, after several years of trial it has not been found that such iron is so well adapted for the manufacture of pipe as the grade of soft weldable steel now generally used for this purpose.

In the year 1904 the writer started a study of the potential differences as found on the surface of iron of various compositions, and has invariably found just as much difference in potential on the surface of very pure iron as on steel or wrought iron of ordinary commercial quality. Subsequent observations, covering several years of service with pure iron, open hearth and Bessemer steel and wrought iron of the quality required for the manufacture of wrought pipe, have confirmed the conclusion expressed by the writer after his earlier experiments; viz., that composition has very little to do with the rate of corrosion

of these metals under water. It should be remembered, however, that conditions underground or inside pipe lines are not the same as when exposed to the atmosphere, so that these conclusions do not apply to materials subjected directly to atmospheric conditions, such as metal roofing, which is another problem.

The tests and experiments referred to indicate that differences in finish and density of the material, particularly the character of the mill scale and how firmly it is attached, usually determine where corrosion starts and how it proceeds. The difference of potential due to surface influences was found to be many times greater than that due to variations in composition in the ordinary run of steel, and predominated over all other influences in nearly every case. These conclusions were tested in the most critical manner and have since been borne out by service tests of several years' duration.

Among the surface influences which directed the course of corrosion, it was found that rust, when once formed, was nearly as potent as mill scale in its effect on corrosion. Some recent work by Mr. James Aston, M. E. of the U. S. Bureau of Mines, confirms these conclusions, but goes further in showing that the influence of rust in some cases is to render the metal underneath the rust anodic. As the mill scale is always the cathode, there is every reason to believe that we may have in certain places on the surface nearly double the difference of potential which was expected and this without reference to the actual composition of the iron or variations thereof. Everything seems to point to this explanation of the cause of pitting as being the true one. Under some conditions of service in water lines or boilers it frequently happens that the tubes, which prove to be of a high standard of quality as regards chemical composition, structure and physical properties of the metal, have rapidly pitted through in places. The difference of potential and the current which thereby flowed from the exposed places to the firmly attached mill scale, especially after the exposed metal becomes covered with rust, affords a satisfactory explanation of the rapid pitting observed in such cases.

The current flowing between two points on the surface of a piece of iron is very difficult to measure accurately; however, we have frequently observed currents as high as one milli-ampere flowing between steel electrodes in McKeesport city water, one plate being clean and the other covered with mill scale. In Table 3 are given some typical readings between plates of the same

area made with a milli-ammeter having an internal resistance of 8 ohms. The electrolyte used was McKeesport city water.

TABLE 3. DATA OF ELECTROLYTIC TESTS ON STEEL AT MCKEESPORT

| Submerged area of plate in sq. in. | Current in milli-amperes | Current divided by the square root of the area of plate | Distance between plates | Material of plates |
|---|---|---|---|---|
| 0.155 | .07 | .18 | 1" | Clean soft steel plate free from scale (positive). Same with light coating of mill scale (negative). Plug of pipe steel (positive). Similar area on skelp with light mill scale (negative). |
| 0.338 | .10 | .16 | 1" | |
| 1.643 | .25 | .20 | 1" | |
| 3.875 | .48 | .24 | 1" | |
| 16.430 | .98 | .24 | 1" | |
| 0.062 | .06-.09 | ... | ⅛" | |
| 0.342 | .14-.18 | ... | ⅛" | |
| 16.430 | 2.02 | ... | ⅛" | |

It might seem at first that these currents are too small to cause serious damage. A rough calculation based on these experiments will indicate the ultimate result from such currents acting continuously with certain submerged areas of electrodes:

1 ampere acting for 6 months, will dissolve 10 lb. of iron, or a plate 12 x 12 x ¼ inches thick.

1 milli-ampere acting for 6 months, will dissolve .144 sq. in. of this plate, making a hole about 7/16-inch in diameter x ¼-inch deep.

0.1 milli-ampere acting for 60 months, will perforate this plate with a hole of the same size.

This rate of pitting is not so far different from that experienced under some conditions of service. The remedy seems to lie in the elimination of dissolved oxygen from water before use. This may be accomplished in practice in at least two ways:

1. By allowing the hot water to come to rest for a few minutes under greatly reduced pressure. As no reliable data could be found on the amount of oxygen retained in solution in water at various temperatures and pressures, a series of experiments were run to determine these constants. The results are given in Fig. 3. Evidently the pressure must be reduced below normal or the temperature raised nearly to the boiling point with the water at atmospheric pressure to get proper separation of oxygen and other gases.

In order to test this out on a practical scale the hot water supply system of the Mellon Institute of the University of Pittsburgh, was altered so as to operate in part as an open system under atmospheric pressure or partial vacuum. As there has

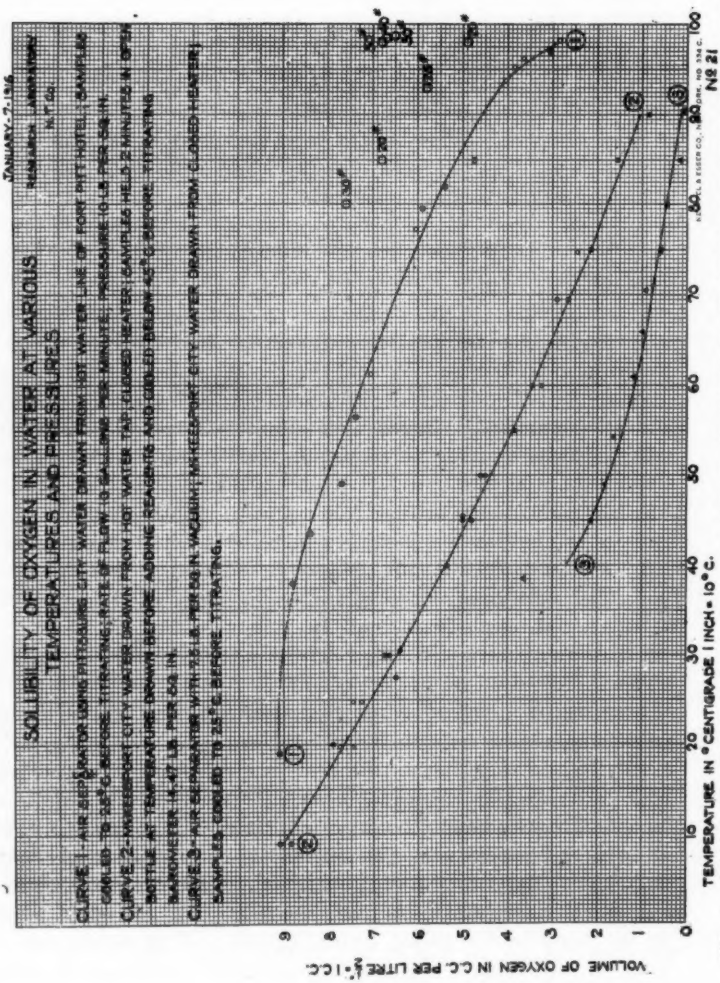



FIG. 3. CHART SHOWING SOLUBILITY OF OXYGEN AT VARIOUS TEMPERATURES AND PRESSURES.

been some delay in getting the preparatory work completed results of this trial will have to be deferred for a supplementary paper.

Fig. 4 is a photograph of some 2-inch wrought iron and steel pipe (galvanized) after thirteen years in the Columbia Baths, Atlantic City, N. J.,—an "open" heating system. The small pipe in the same picture shows the condition of some copper pipe used under the same conditions in a "closed" heating system for only six months. At the Columbia Baths the salt water was heated to about 180 degrees Fahrenheit in an open tank from which it was run by gravity to the system. This pipe was in continuous

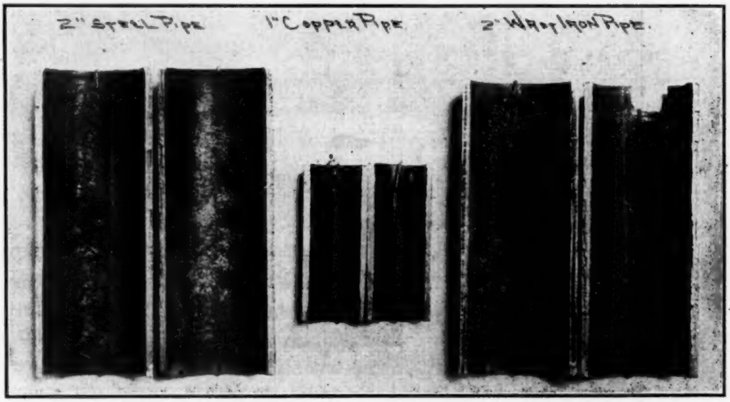



FIG. 4. SECTIONS OF GALVANIZED PIPE AFTER 13 YEARS.

use during the season for this period. The galvanized pipe was practically as good as new, showing that even salt water is practically harmless when de-aerated to this extent.

2. An alternative method of reducing corrosion in water lines by satisfying or "fixing" the free oxygen was tried out by the writer several years ago, using clean iron turnings. It was found difficult to get the scrap free from oil, and after rusting had progressed for some time there was a tendency for the mass to cake together and so impede the flow. By using sheet iron, so formed as to provide a large number of channels with about ¼-inch clear passage through which the hot water slowly percolates, we expect that these difficulties will be overcome. Some determinations of the rate at which the free oxygen is removed from water by this system are given in Fig. 5. The rate of rusting varies with the surface condition of the plates,

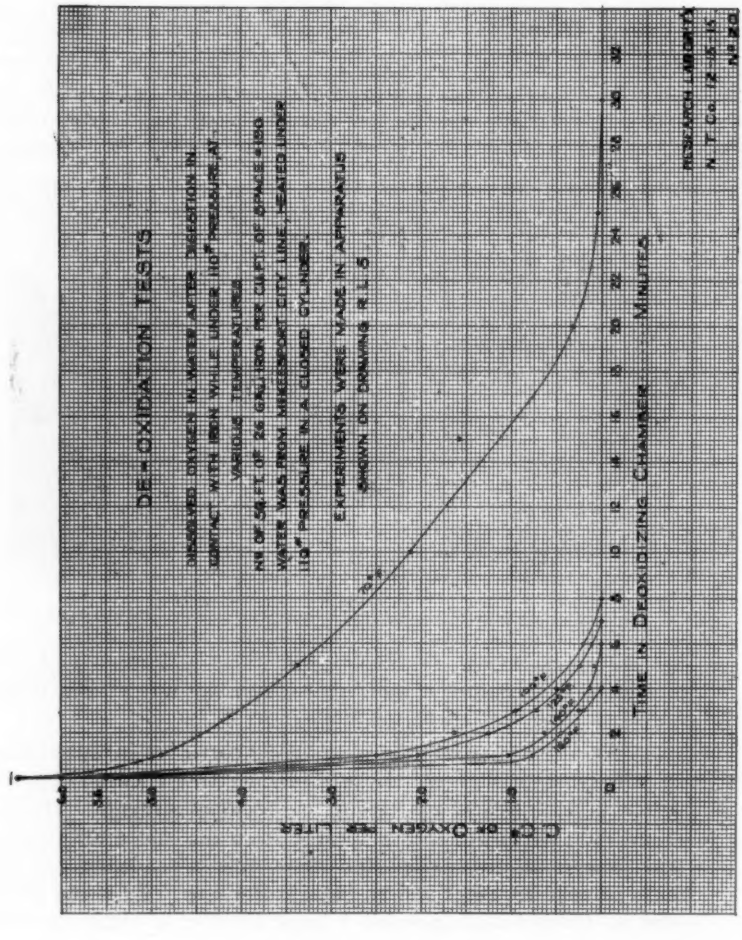



FIG. 5. CHART SHOWING RATE AT WHICH FREE OXYGEN SEPARATES FROM WATER.

becoming more rapid as the surface is covered with a good coating of oxide. The speed of rusting is 50 per cent. more rapid at 110 lbs. per sq. in. pressure than at atmospheric pressure, and, of course, the time required to "fix" the free oxygen of the water varies with the amount of surface of metal exposed per cubic foot and other conditions which are liable to vary. For these reasons, the results given in Fig. 5 are only relatively correct for the conditions stated.

On this principle, two small plants have been equipped to carry out this method of treatment in practice. These systems were installed at places where considerable trouble has already been developed through the clogging and corrosion of galvanized pipes.

These plants, which have only been operating a short time, show a reduction of oxygen contents from 8 or 9 c.c. per liter to 0.1 to 1 c.c. per liter according to the rate of flow and temperature. At present it seems desirable to design the plant so that the oxygen contents will be less than 1 c.c. per liter at all times, at which point corrosion seems to be reduced to a negligible amount. Some more definite data on this point will be available after these plants have been in operation for several months. The indications are that the rate of rusting of the plates, and hence the efficiency of the apparatus, will increase with time. Water should be in contact with the plates for at least ten minutes.

Similarly, the corrosion of low pressure steam lines will be found to depend principally on the amount of oxygen which finds access to the system. The return lines naturally suffer the most and are usually the first to show failure. Condensed water when freed from oxygen in solution is harmless, and will not even tarnish bright iron after months of exposure; but this water, on account of its great purity, has greater capacity for solution of oxygen than the average natural water and is therefore apt to be very corrosive when aerated. This may be prevented in large measure by using an open feed water heater and keeping the water over 185 degrees Fahrenheit.

In some cases the surface of the pipe may be protected with a film of oil deposited from the steam. The writer's attention was recently called to the satisfactory results obtained in some buildings using exhaust steam which on investigation was accounted for by the thin film of oil found on the inside of these pipes. This was such an interesting matter that we made some tests in the research laboratory on long lines of new pipe and found that mineral lubricating oil, when dropped into a pipe

carrying steam under pressure at the rate of two drops per minute, was carried forward in a fine state of division and in a few minutes was found condensed in a uniform film in the pipe about 160 feet from the lubricator. While this simple means of protection would perhaps be objectionable in some cases, there are many steam heating systems where the oil could do no harm and might result in considerably prolonging the life of the lines. Of course, nothing but a good grade of mineral lubricating oil should be used, and the supply should be regulated by a reliable sight feed lubricator.

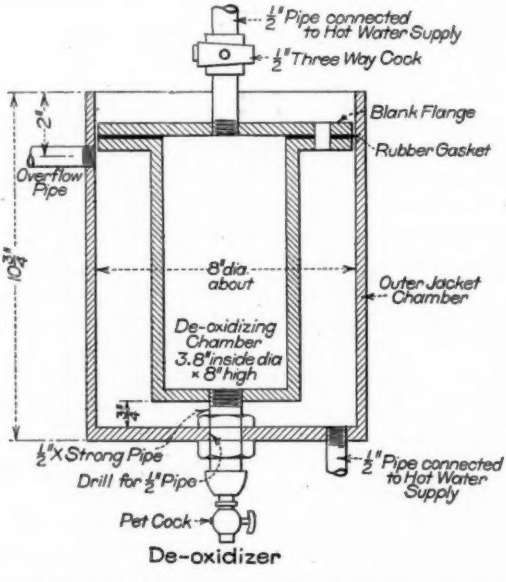



FIG. 6. LABORATORY APPARATUS USED TO DETERMINE RATE OF DEOXIDATION GIVEN IN FIG. 5.

Drying kilns and greenhouses use annually a very large amount of pipe for steam heating and under certain conditions are subject to rather rapid deterioration from inside corrosion due to the large amount of water condensed in the returns. A case of this kind was investigated by the writer last summer, where corrosion had developed on the low temperature end of the system due to oxygen brought in with the feed water. The same plant had been operating for fifteen years without trouble using an open hot well kept at high temperature. Due to enlarged demands on the system certain changes were made by

which the temperature of the water from the hot well, from which the feed pumps drew their supply, was reduced below 120 degrees Fahrenheit. At this temperature the amount of oxygen in solution is about three and one-half times the amount found in water at 180 degrees Fahrenheit, most of which was of course absorbed in the water of condensation in the returns, making possible the corrosion of the pipe. A higher temperature in the hot well and the use of a lubricator were recommended.

Summarizing very approximately, the influence of various factors on corrosion, it appears from the experience we have at present that developments in the metallurgy and manufacture of steel pipe promise to add 50 or perhaps 100 per cent. to the life of pipe compared with the service obtained under like conditions ten or twelve years ago. However, it appears well within the bounds of possibility to predict that de-aeration of the water, through the use of plants designed with this end in view, should at moderate expense increase the life of some piping systems four or five times.

Such a possibility of conservation of material is surely worthy of careful consideration by heating engineers and architects.

## DISCUSSION

A. A. CARY: Referring to Mr. Speller's statement that: "The inside of pipe is subject to peculiar conditions not to be compared with external corrosion, and the inside surface is particularly vulnerable in that protective coatings are difficult to apply, therefore more liable to be defective," I have successfully applied a coating to the inside of pipes by using a light whitewash (made by dissolving ordinary building lime in water), which is mixed with hot water flowing through such pipes and soon a coating of lime is deposited upon the interior surface of the pipe. Where such a coating exists (either in a pipe or in a boiler), no pitting action will take place.

The process of deoxidizing water, referred to by Mr. Speller, brings to my mind another process that was used in England about 25 years ago, known as the Anderson process of water purification. Mr. Anderson used the heavy steel turnings produced in a machine shop which were treated with a cleansing solution of potash or soda and after being cleaned from their coating of oil, were put into a long revolving barrel similar to the tumbling barrels used in foundries, but larger and much longer. The water, holding air in

solution, was led into this barrel, through the hollow shaft (or trunnion), at one end and passed out of the hollow shaft at the other end horizontally. The barrel was revolved slowly and the water flowing through it at a temperature of less than 200 deg. Fahr., was thus brought in contact with the bright steel turnings it contained.

The surfaces of the bright steel turnings rusted rapidly, as they abstracted the oxygen from the expelled air, and as the turnings were constantly being tumbled, their faces were kept polished clean from the rust which accumulated for reoxidation as the continuous stream of fresh-air-charged water continued to flow through the barrel.

Mr. Speller, in his paper, refers to the protective effect of a coating of oil on the inner surface of pipes and he speaks of an oil dropping method for introducing this oil. I have been very successful in evenly coating the inner faces of both pipes and boilers by a simple method of filling the pipe or boiler with water, pouring a light oil on the upper surface of the water and allowing the water to escape very gradually from a bottom outlet. The oil, floating on the surface of this water, is thus gradually made to flow along the interior surfaces, to which it adheres and leaves a good uniform film or coating behind it. By repeating this process or by adjusting the rate of water outflow, any desirable thickness of oil coating upon your interior surfaces can be built up.

Mr. Speller refers particularly to the chemical effect produced when the rusting or pitting of pipes takes place and in this connection it is interesting to trace just how this destructive oxygen and other gases originate in the hot water pipes under discussion. When water is heated, just before reaching the boiling point (from 150 to 200 deg.) air is forced out of the water and it is the usual custom to lift the safety valves in boilers to get rid of this air before the real generation of steam begins. Air contains nitrogen and oxygen, the first an inert gas having no corrosive effect in iron or steel piping while the second is responsible for the rusting and pitting action found and its action is greatly accelerated by its association with a small amount of carbonic acid, which is commonly present in the air.

In air we find approximately one volume of oxygen mechanically mixed with four volumes of nitrogen. When this air is dissolved in water, owing to the greater solubility of the oxygen, I have found by actual test that these two gases exist together in the proportion of one volume of oxygen to 1 87/100 volumes of nitrogen.

Thus we find that with this greater concentration of the oxygen in the air liberated from the water by heating, we have more than

double the oxidizing capacity of the air per each unit volume, and with the pressure of carbonic acid gas and moisture we have a highly oxidizing agent to bring against the metal surfaces of our pipe.

No less than five different theories have been advanced to account for the corrosion of iron, as follows: Oxidation, the acid theory, the electrolytic theory, the hydrogen-peroxide theory and the biological theory. The acid and electrolytic theories are the most reliable theories advanced and most worthy of our consideration. With this considerable disagreement, we find it pretty difficult to work from a definitely established cause in order to remedy the defect, and we are obliged to follow the "cut and try" method and produce a material based upon the results of past experience guided by such scientific reasoning as a knowledge of metallurgy will supply.

After years of experience, we are apt to adopt some standard in our minds, to which we compare all new similar productions and we inquire, when pressed to use them whether our standard has been equaled. Fair comparisons are very essential to form a correct judgment of the respective merits of the new products and we must have some understanding of the underlying principles of the subject in order to reason correctly.

I have endeavored to present some simple metallurgical facts in table form which may help us in considering this subject, and this form of presentation was suggested to me by a very extended table published in the Iron Age a few years ago by Eliot A. Kebler.

## BRIEF STATEMENT OF THE METALLURGY OF IRON AND STEEL

### I

**Iron Ore—Contains iron and oxygen and impurities.**

**Iron Ore—Smelted in blast furnace removing oxygen and part of impurities and adding carbon, makes pig iron.**

**Grey Forge Pig Iron—Melted in a puddling furnace, then balled, squeezed and rolled, makes muck bar.**

**Muck Bar or Wrought Scrap, cut into short lengths, piled, heated and rolled, makes wrought iron.**

**Muck Bar—Treated as above and rolled into strips, makes skelp iron.**

**Skelp Iron—Bent into the shape of tubes and welded, makes iron pipe.**

### II

**Muck Bar or Steel, melted in a crucible with charcoal, makes carbon steel, tool steel, or crucible steel.**

**Muck Bar or Steel, treated as above with tungsten added to raise the temperature at which it softens, chromium to give toughness, and vanadium, titanium, aluminum or other metals to improve the quality, heated to a high, then to a lower heat, makes high speed steel.**

Bessemer Pig Iron—Direct from blast furnace or melted in cupola, poured into converter with air blown through it to burn out the impurities, makes Bessemer steel.

Pig Iron—Molten, or in pig, with or without scrap, when purified in open hearth furnaces, makes open hearth steel.

Low Phosphorus Pig Iron—Treated as above in an acid (silica or sand) lined furnace, makes acid O. H. steel.

Basic Pig Iron—Treated as above in a basic (dolomite) lined furnace to remove phosphorus, makes basic O. H. steel.

Basic O. H. Steel—With only about 1/10 of 1 per cent. impurities is called by various trade names, such as toncan metal, genuiné open hearth iron and American ingot iron.

Vanadium Steel or Manganese, (over 7 per cent.) titanium, or nickel steel is made by the addition of these metals, all being called alloy steel.

Steel—Purified in an electric furnace, makes high grade steel.

III

Steel—Is cast into ingot molds usually about 19 in. square and about 6 ft. long, making ingots.

Ingots—Are rolled into blooms or billets.

Billets—Are rolled into bars and small shapes.

Billets—Are rolled into steel skelp.

Steel Skelp—Bent into the shape of tubes and welded, makes steel pipe.

Billets—Are pierced, rolled and drawn through dies, making seamless tubes.

As to my standard of comparison regarding corrosion in pipes, in the late eighties I was called upon to remove an old wooden flooring in the large basement of a factory in this city that about 30 years before had been used as a tannery and leather manufactury, in order to prepare it for the installation of some new machinery. I found old tanks in this basement and a system of piping connecting them, which had been buried in the floor for all these years, and was surprised to find the pipe in such excellent condition, that, after taking it out, I had it cleaned and rethreaded for use again in another underground position. I found it to be genuine wrought iron pipe.

Other steel pipes, which had been in service but about five years buried below the same floor was found to be in such corroded condition that they were thrown into the scrap. That was one of my early lessons as to the superiority of wrought iron pipe as compared with steel pipe.

When in the boiler business a number of years ago, the concern with whom I was connected furnished water tube boilers for a plant near this city, in which charcoal iron tubes were specified and used. A number of the tubes in the boilers burned out due to scale and were replaced by a local boiler maker with steel tubes bought in the open market. After this plant had been in operation about two years, the company failed and the plant was shut down. About two years after this I was called upon to go to the plant and examine the boilers for a pros-

pective customer who wished to purchase them. When I got into the furnace, I was surprised to find so many of the tubes black and in good condition, but the steel tubes which had been put in by the plant owners were all covered with rust so that I had no difficulty in recognizing them.

These are but two examples out of many which impressed upon me the superiority of wrought iron pipe and tubes to resist corrosion, and I have since been looking for steel pipes or tubes which would equal those made of wrought iron.

Referring to the tabulation wrought iron is made from pig iron which is melted in a reverberatory furnace where much of the original impurities are removed (i. e. silica, carbon, etc.), by the oxygen from the iron ore or iron scale at the bottom of the furnace and from the oxidizing flame used. The temperature used is too low to maintain the iron (when low in carbon) in a melted state, and the mass gradually "comes to nature" due to the forming of pasty particles in the bath which stick to each other and finally, when all of the iron is decarbonized these plastic masses increase and come together. They are finally gathered together to make the puddle ball in which condition the mass is removed from the furnace, carrying with it a very small amount of cinder (or silicious slag) which is well distributed all through the iron, and also other impurities, such as phosphorus, sulphur, etc., which should finally be reduced to small fractions of one per cent. to produce a desirable metal.

Wrought iron is tough, ductile and has a distinctly fibrous fracture. It has a wide range of welding temperatures.

Wrought iron, so-called, is sometimes made by another method known as the "busheling process" by which the start from the selected pig iron, followed by the treatment in the puddling furnace, is omitted. The metal used in this process is obtained principally from the junk yards and may contain parts of old scrapped boilers, barrel hoops and all kinds of miscellaneous scrap; even steel scrap often finds its way into such conglomerate collections.

With such so-called "wrought scrap" worked into skelp bars and made into pipe, how can we reasonably expect to obtain a desirable quality of wrought iron pipe? Thus we see the great necessity, when making a comparison between the merits of steel and wrought iron pipe, to know exactly the process by which our sample of wrought iron pipe was made and in order-

ing such pipe for use in our work it pays well to use a careful specification and to purchase from a reliable manufacturer.

By reference to the tabulation, we see that all modern commercial steel is made by actual melting processes. All of the various grades of steel require the metal to be reduced to a fluid state, instead of being produced from a pasty, plastic mass, as is the case with wrought iron.

The old time practice of defining the difference between steel and wrought iron: one as metal which would harden and temper, and the other, one which would not, is no longer continued. Many soft steels now produced cannot be tempered. Every ferrous product of the crucible, the bessemer process and the open hearth process is commercially classified as steel.

Steel is very much more sensitive to heat treatment than wrought iron, either during the process of manufacture or afterwards, and the range of temperatures through which perfect welding can be obtained is much more limited than in the case of wrought iron. Steel has a crystalline fracture, which varies with its quality and degree of temper, and a fracture shows that it lacks the fibrous structure and toughness that is found in wrought iron.

Thus we see that in these two metals, we have many totally different qualities. The fibrous wrought iron of a desirable quality with a fraction of one per cent. of contained carbon and with the small percentage of slag distributed well through its mass has proved itself, when formed into pipes, to resist corrosion when placed in the most trying damp positions for many years. Our friends, who for many years have been struggling with the crystalline, slag-free steel, have long been trying to produce something just as good and they are apparently still "at it."

MR. CARSON: I am much interested in Table 2, showing results of investigations of corrosion. It is not clear to me how we can get at the subject of the pits over the surface of pipes. It seems possible to make any percentage comparison we may choose without in this way showing a true comparison of relative corrosion.

As to the matter of decrease of corrosion in pipes, I happened to be in a New York bathhouse plant the other day where they were taking out some wrought pipe lines that had been used only about eighteen months. The cast iron fittings which had been used over and over again showed no apparent deterioration. That led me to think it might be well to put in cast iron pipe and I suggested that they do this.

Boiler economizers with cast iron pipe have been used in this country and in England for the past 35 years or 40 years, and I learn that attempts have recently been made to use wrought iron pipe with the result of the piping only lasting about a year or two, whereas cast iron pipe has been in service in these lines for 35 or 40 years without rusting. There are many places where cast iron pipe can be used to good advantage in heating work.

J. A. Kinkead: Mr. Speller has done more in the past fifteen years than any one else in this line of work. I was also interested in Table 2. There are some references given there, and I am familiar with the first. As I remember the results of the investigations in this installation, they showed that the specifications called for genuine wrought iron pipe. The tests were made on a number of pipes that had failed in service. Arguing on the merits of iron or steel pipes, they said that 0.8 of the pipe in service was steel and the rest was iron, and the tests showed that the iron pipes that failed were less than the steel. I think that this is a point that would be overlooked in glancing over his article.

I note in the last paragraph of his paper, Mr. Speller states that the present "developments in the metallurgy and manufacture of steel pipe promise to add 50 or perhaps 100 per cent. to the life of pipe compared with the service obtained under like conditions ten or twelve years ago." It may be that there is a difference between practice and theory in the aspect of this point. We all hope that all processes are constantly improving all the time. But I know that in my work lately, when I have endeavored to obtain material under specifications of a few years ago, I have found it impossible to do so. I was told by the men that the manufacturers could not get raw material, and that when they did get it, the pressure of business has necessitated the making of larger ingots due to the greater quantities produced, and that it was not possible to get the old grade of material.

The Author: As to Mr. Carson's suggestion that cast iron pipe be used for hot water, I rather think that you would find it to be more satisfactory to treat the water and thus remove the root of the trouble. While cast iron has shown some conspicuous cases of longevity, it has also shown itself susceptible to rapid disintegration (graphitization) under certain conditions. The question of whether cast iron can be safely used in pressure systems can well be left to the engineers who are responsible for the design and safety of such installations.

The Anderson process was introduced as a means of purifying water for drinking purposes without reference to corrosion. It did not go far enough to have an influence on the corrosion of pipe. Anderson passed the cold water over scrap iron or agitated it with scrap so as to form a small amount of hydrated oxide of iron as a coagulant. The conditions were not such as to have a material effect on corrosion, nor was that object in view at that time.

# No. 410

# THE VENTILATION OF LIVING QUARTERS

By the Chicago Commission on Ventilation

OUR ideal is that the conditions of a spring day outdoors, with sunshine and a cool breeze should be approximated as nearly as possible within doors.

While authoritative data on health conditions of high-grade residences are hard to get, it is a striking fact that mortality statistics show a comparative tuberculosis death-rate for hotel domestic servants who live indoors, of seven times that of locomotive engineers, who live outdoors. (Supplemental Vol. from Reg. Gen'l 65th Annual Report Gt. Britain Pub. 1908.)

In a book by F. C. King—"Ventilation of Dwellings, Rural Schools and Stables," there is a description of an experiment with a herd of 20 milch cows. They were confined in a fairly tight stable. During a period of 12 days, observations were carried out as follows:

2 Days—Free ventilation.
2 Days—Windows and doors closed tightly.
2 Days—Free ventilation.
2 Days—Windows and doors closed tightly.
2 Days—Free ventilation.
2 Days—Windows and doors closed tightly.

The cattle suffered no apparent discomfort during the periods of bad ventilation and ate practically the same amount of food. On the bad ventilation days, however, each drank 11.4 lbs. more water, and at the end of each two-day bad ventilation period, each had lost 10.7 lbs. which they regained under good ventilation. The weight of milk produced decreased an average of .55 lbs. per head each bad ventilation day.

Health statistics indicate that when artificial heating begins, the sickness rate increases, particularly in the complaints influ-

Presented at the Annual Meeting of The American Society of Heating and Ventilating Engineers, New York, January, 1916.

enced by air quality and temperature conditions. As the state of mind is influenced by the body conditions and as bad housing is proven to affect deleteriously the morals, it is possible that the so-called Fall crime wave is a result not only of the cold and the fear of the cold to come, but of the radical change in air quality and temperature due to closed windows. From this, it appears that some active interest in the air conditions in living quarters, as well as those in factories and schools, will be repaid.

With direct steam or hot water heating, weather stripped or steel windows, vestibules on all doors, gas or electric cooking, and double air-tight furred and sound-proofed walls, the air leakage is negligible, and the moisture content becomes very low in a short time. Dryness and absence of drafts, and a constant high temperature cause the bodily resistance to be lowered and the physical tone to be depressed. We quote from Leonard Hill and associates in "The Influence of the Atmosphere on Our Health and Comfort in Confined and Crowded Spaces," (Smithsonian Institution 1913) as follows:

"We believe that infection (colds) is largely determined (1) by the mass influence of the infecting agent: (2) by swelling of the mucous membrane of the nose: (3) by the sudden transition from warm to cold surroundings, which checks the immunizing mechanisms. Colds are not caught by exposure to cold per se as is shown by the experience of arctic explorers, sailors, shipwrecked passengers, etc. We have very great inherent powers of withstanding exposure to cold. The bodily mechanisms become trained and set to maintain the body heat by habitual exposure to open air life. The risk lies in overcrowding, so that infection becomes massive, and in overheating our dwellings and overclothing our bodies, so that the mechanisms engaged in resisting cold become enfeebled and no longer able to meet the sudden transition from the warm atmosphere of our rooms to the chill outside air of winter."

It is hopeful for our future that a rapidly increasing proportion of the people sleep with windows open. Nature assists this habit, for nearly everyone accustomed to sleeping in a draft is unable to sleep well unless the draft be present. It seems to be an instinctive sub-concious saving trait, but unless we encourage it, it does not persist noticeably during our waking hours. Years ago a popular belief obtained that night air was bad for people. We were appraised of the remarkable discovery that if one kept his windows shut at night, he escaped malaria even in a malarial

country. Most emphatically we desire to brand this fallacy, the basis of which, of course, was the malaria bearing mosquito.

Night air in general is good air. It is the same free outdoor air which has been subjected to the sterilizing influence of the sun and the chemical influence of the plants, still further improved by the physical influence of having had its dust in a large part removed by the deposition of its moisture as dew or hoar frost. (Particles of dust form the nuclei of drops of moisture.) The outdoor night air is infinitely better air than any night air contained in houses, retaining as it must the dust evolved by the day's activities both indoors and out. Tests with culture plates have seemed quite clearly to demonstrate materially less dust outdoors at night than in a bedroom having wide open windows and a cross draft.

Natural air circulation is caused by temperature difference inside rooms, and probably the same temperature differences cause the winds outside. The sun warms the land. The land warms the air, which rises, and cooler air rushes in to take its place. Every cold wall or window causes a down-current of air, and every radiator or other heat source, even the body of an animal, causes an up-current of air. Such currents, however, are not usually sufficient in themselves to render the beneficial effects which many careful tests have shown are gained by rapid air circulation, as by fans or by drafts through open windows. The natural currents, however, will cause a gradual air movement in houses, particularly in those having more than one story, and may be utilized in promoting ventilation, provided proper inlets and outlets are furnished.

Four adult pupils of the Chicago Normal School made studies of the air currents in four residences. Attached to this report are drawings of the houses, showing the currents and setting forth the pertinent temperature, moisture and wind conditions both indoors and out. The air currents were traced by watching the smoke from burning Chinese punk placed in various parts of the rooms, and in the several openings, and by observing the direction taken by fine ravelings of silk floss. The following is a synopsis of all of the conclusions set forth by the students:

By "house" is meant a detached building or a home in an apartment building. Natural ventilation without fans or heated flues is meant:

1. The effect of the direction of the wind outside is very much influenced in its relation to the currents inside of a house

by the local conditions of the adjacent buildings and obstructions and by the house itself.

2. Air currents as a general rule seek the easiest way in and out of a house.

3. The more inlets there are open on the side facing the wind the better the ventilation, provided there are openings on the leeward side.

4. Adequately to ventilate a home requires sufficient inlet and outlet openings.

5. The efficiency of ventilation increases with any increase in the difference between the temperatures indoors and outdoors.

6. Better results are usually possible when ventilating the entire house than when ventilating only one room.

7. Proper distribution of fresh air is more difficult to attain than proper volume. Part of a room may receive good ventilation, while other parts are stagnant.

8. Furniture exerts a material influence on air currents, and conditions may be improved by intelligent placing of the furniture.

9. Eddies tend to form wherever the air currents are blocked.

10. The distribution of the air is best obtained by proper distribution of the inlets and outlets.

11. An open stairway tends to cause a current of air to rise through it, even though the windows may be closed.

12. An open shaft, like a large chimney centrally placed, would assist materially in ventilating a house.

Most of the city homes with which we have to do, are heated by direct steam radiators, with no special provision for ventilation. Apartment buildings as a rule are designed for the least possible cost per unit and their heating and ventilation facilities are worse than those inherent in the cheapest stove-heated tenements, which are ventilated a little through the stove pipes.

Where the occupants care about comfort, and most of them do, it is easier to open a window when too warm than to stoop and screw down a radiator valve. When radiators are placed, as is usual, under windows, and two windows are open causing a cross draft, the heat from at least one of the radiators passes out of doors and is wasted. Thus, the owner and the janitor become enemies of ventilation. It is a temperature consideration more than any other consideration that causes most of the ventilation we get by windows. Probably this instinctive and ignorant act is nature's provision to save the race from destruction.

The building of light courts with glass enclosed tops on them should be prohibited by law. The necessity of light in any place indicates a similar necessity for air. Light courts will in many cases make quite efficient vent flues if given a chance. The ordinary small ventilators placed above such skylights over light courts, are of no avail, and as far as their service goes might almost as well be omitted. For ventilating purposes our observations indicate that the efficiency of an open top chimney with a tapering finish is the highest, and that any obstruction as a so-called ventilator is a real obstruction, only to be countenanced as it may be required to keep out weather.

It is not difficult or expensive, however, in the designing of new apartments, to arrange for gravity ventilation. We have in mind the Woman's Christian Association at Dayton, Ohio, the small sleeping rooms of which have each but one window. There are large vent shafts terminating in chimneys, which lead from the ceilings of the sleeping room corridors on each floor. These are, of course, provided with means of adjustment. In summer especially, when the windows and transoms are opened, an excellent cross draft is obtainable, and at no time is the familiar stale sleeping room odor noticeable.

A little care in the placing of the radiators in the rooms themselves will permit of window ventilation without excessive heat waste. If the radiators are placed near interior walls instead of under the windows in rooms of ordinary size, the heating results will be equally as good in practically all cases. The windows will be cleaner and more accessible, and the room will be pleasanter, because one can get close to the window, and a very fair air change can be made with only one window even when there is no breeze outside, by opening at the top and bottom at the same time. The reason for this is as follows:

Warmed air rises to the ceiling and displaces cooler air, which settles to the floor. There is very noticeable pressure out at the ceiling of any heated room, also at the tops of the windows and doors. A leakage at these points constantly is occurring, and to replace this leakage there is a negative pressure at the floor. Air always comes in through cracks low down, bottoms of windows, etc., in heated rooms. The radiators help this, and very small openings at the tops and bottoms of windows will give very much better results than large openings at the top or bottom alone. The results when the radiators are not directly under the windows are that the ventilation costs only for the heat necessary to warm the changed air, as no great amount

of heat may pass directly out. These remarks apply to houses as well as to apartments heated by any direct means, as steam, hot water or electricity. It is difficult to formulate a rule for window opening—in general, the top and bottom openings should be as large as can be endured with comfort.

Screens are required by law for rooms used for the preparation of food. The law does not compel screening of the whole window frame opening, however, with the result that when the upper parts of the windows are open the screens are of no avail. The law should be corrected.

Screens for residences are almost universally applied to the lower sash openings only, and as a result the screens do not permit in hot weather especially, of the most efficient use of the windows. All windows everywhere, which have screens at all should have them for the entire window opening, and so arranged that top and bottom sash may be opened as much as desired.

Houses having independent direct radiation heating systems, can easily be ventilated so as to give a reasonable supply of fresh air by installing a central indirect radiator, say, under the main hall with an outdoor connection for air supply, using open fireplace chimneys for outlets. Registers in the floor should never be used for air inlets. Flues should be provided so that the air may enter through a clean conductor, and if such a flue is provided it is often possible to place the radiator in it, thus raising it higher above the boiler, where it will operate more efficiently. The often unused space under the lower part of the stair, too low for closet purposes, is suggested. Fresh air inlets in the floor tend to be dust receptacles and are extremely objectionable, with any system of heating.

It is easy and not costly in new buildings to provide vent flues alongside of the chimneys, which will usually be operative, since the chimneys will warm them.

Houses having furnace heating systems are per se ventilated to some extent, even when the air is recirculated. The fact, however, that such recirculation installations do at times possess evil odors, shows the need of fresh air. It is to be regretted that furnace heating systems to meet the fuel cost competition of direct radiation systems, have prostituted their fundamental virtue, and abandoned fresh air intakes and foul air outlets.

The effective way to care for all houses having indirect heaters, such as furnaces, or steam or hot water radiators through which fresh air is passed, is to install electric fans.

For instance, a small fan of the ordinary disc type will, if operating in the supply duct leading to such a heater, cause the transmission of about three times the amount of heat from heater to air as will pass by gravity. This insures quick heating in the morning, and the ability, when the house is to be crowded as by an entertainment, to provide by continuous operation of the fan for excellent ventilation. An ordinary 16-inch disc fan has been shown to deliver through a heater and into a room as much as 1,500 cubic feet of air per minute. In the house, the fan in the air supply duct would be used intermittently, controlled by a switch on an upper floor.

An electric fan in a household is a great advantage for many reasons. By creating as it does a current of air, adjustable and already warmed, the fan increases the skin evaporation, thus cooling and toning up the body, and assisting in its temperature control. By driving the air against a direct radiator, the fan will increase the heat given off by the same, very materially being an active assistant to heating the house in very cold weather.

If there were more appreciation generally of the facility with which kitchen odors, smoke from cooking, etc., can be removed by a fan, and what a trifling cost is incurred in operating such a fan, it is sure that kitchen exhaust fans would be more general, and that proper hoods and special flues for their discharge would be provided in new buildings. Fans for this purpose should be arranged with their motors protected from the air current caused by the fan.

When ample fresh air cannot be provided continuously and at a satisfactory temperature, inevitably if the heating system is in operation the moisture content becomes deficient. Great improvement can be made by providing for artificial moisture introduction.

For furnace heated buildings, evaporating tanks can easily be arranged, with a constant water supply and even with automatic humidity control.

For direct radiator steam heated buildings, there are noiseless and satisfactory automatic valves which introduce steam directly to the air.

For direct hot water radiator heated buildings no very satisfactory humidifying scheme is commercially available, but some hope is held out that good results may be obtained from either a flash type boiler in the firepot, thus giving steam for jets in

the rooms, or by a gas fired auxiliary boiler serving the same end.

For buildings having indirect radiators through which fresh air is introduced, where steam is used, jets may be placed for blowing the steam directly into the air.

Where hot water is used, the air after passing the radiator may pass a spray or rain of hot water which is nearly as effective as steam.

These jets, whether of steam or water, should be controlled by automatic means which are now commercially available, and which are reliable.

Every house should have a simple hygrometer as well as a thermometer.

The Chicago Commission on Ventilation in its 1915 report published a "Comfort Zone Chart." The term "comfort zone" means that there is a maximum temperature witn a minimum relative humidity, and minimum temperature with a corresponding maximum relative humidity between which limits, the occupants of a room are comfortable. In other words, there seems to be no best temperature and also no best relative humidity; but the maximum temperature at which one is comfortable will be associated with a minimum relative humidity, and the minimum temperature for comfort will have associated with it a maximum relative humidity. Under the conditions with which we were working, we found that a temperature of 64 to 70 degrees with a corresponding relative humidity of 55 to 30 per cent., seems to be the limits; that is, the comfort zone for us was between 64 degrees and 55 per cent. and 70 degrees and 30 per cent. It is worthy of note that with a temperature below 67 or 68 and with a proper relative humidity, the occupants were better able to give attention to their work than if the conditions were otherwise.

We reprint the comfort zone chart below, for convenience and reference. (See page 47, Report of the Chicago Commission on Ventilation.)

COMMITTEE ON THE VENTILATION OF LIVING QUARTERS.

GEORGE BEAUMONT,
PROF. J. W. SHEPHERD,
SAMUEL R. LEWIS, *Chairman.*

## RELATIVE HUMIDITY TABLE

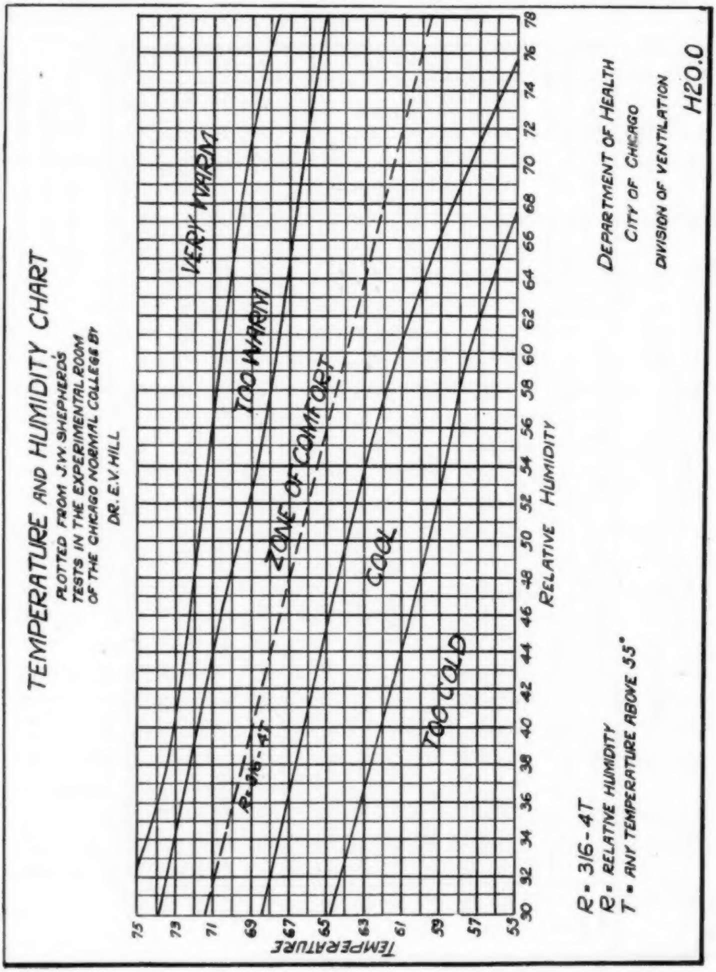
DEGREES FAHR. BAROMETER 30" OF MERCURY

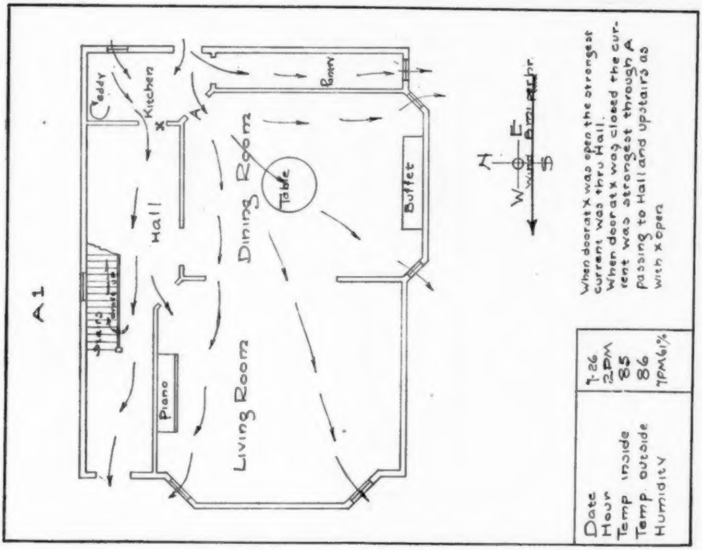
| AIR TEMP. t | DEPRESSION OF WET BULB THERMOMETER (t-t') | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 30° | 89 | 78 | 67 | 56 | 46 | 36 | 26 | 16 | 6 | | | | | | | | | | | | | | | | |
| 35° | 91 | 81 | 72 | 63 | 54 | 45 | 36 | 27 | 19 | 10 | 2 | | | | | | | | | | | | | | |
| 40° | 92 | 83 | 75 | 68 | 60 | 52 | 45 | 37 | 29 | 22 | 15 | 7 | 0 | | | | | | | | | | | | |
| 45° | 93 | 86 | 78 | 71 | 64 | 57 | 51 | 44 | 38 | 31 | 25 | 18 | 12 | 6 | | | | | | | | | | | |
| 50° | 93 | 87 | 80 | 74 | 67 | 61 | 55 | 49 | 43 | 38 | 32 | 27 | 21 | 16 | 10 | 5 | 0 | | | | | | | | |
| 55° | 94 | 87 | 82 | 76 | 70 | 65 | 59 | 54 | 49 | 43 | 38 | 33 | 28 | 23 | 19 | 14 | 9 | 5 | 0 | | | | | | |
| 60° | 94 | 89 | 83 | 78 | 73 | 68 | 63 | 58 | 53 | 48 | 43 | 39 | 34 | 30 | 26 | 21 | 17 | 13 | 9 | 5 | 1 | | | | |
| 65° | 95 | 90 | 85 | 80 | 75 | 70 | 66 | 61 | 56 | 52 | 48 | 44 | 39 | 35 | 31 | 27 | 24 | 20 | 16 | 12 | 9 | 5 | 2 | | |
| 70° | 95 | 90 | 86 | 81 | 77 | 72 | 68 | 64 | 59 | 55 | 51 | 48 | 44 | 40 | 36 | 33 | 29 | 25 | 22 | 19 | 15 | 12 | 9 | 6 | 3 |
| 75° | 96 | 91 | 86 | 82 | 78 | 74 | 70 | 66 | 62 | 58 | 54 | 51 | 47 | 44 | 40 | 37 | 34 | 30 | 27 | 24 | 21 | 18 | 15 | 12 | 9 |
| 80° | 96 | 91 | 87 | 83 | 79 | 75 | 72 | 68 | 64 | 61 | 57 | 54 | 50 | 47 | 44 | 41 | 38 | 35 | 32 | 29 | 26 | 23 | 20 | 18 | 15 |
| 90° | 96 | 93 | 89 | 85 | 81 | 78 | 74 | 71 | 68 | 65 | 61 | 58 | 55 | 52 | 49 | 47 | 44 | 41 | 39 | 36 | 34 | 31 | 29 | 26 | 24 |
| 100° | 96 | 93 | 89 | 86 | 83 | 80 | 77 | 73 | 70 | 68 | 65 | 62 | 59 | 56 | 54 | 51 | 49 | 46 | 44 | 41 | 39 | 37 | 35 | 33 | 30 |

RELATIVE HUMIDITY

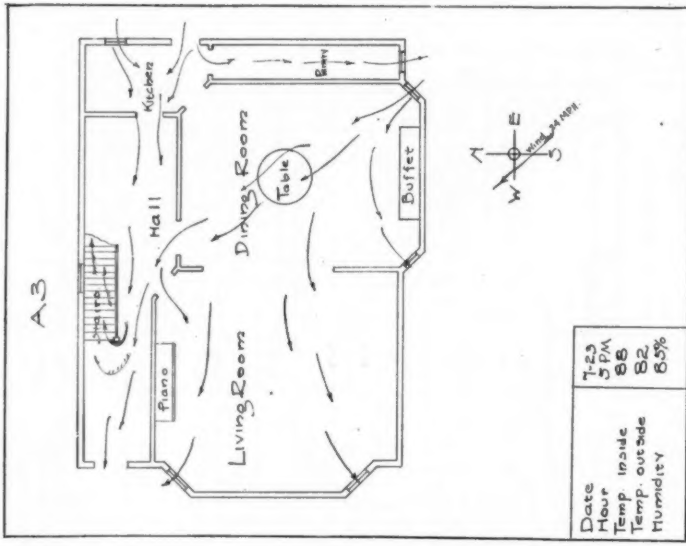
DEPARTMENT OF HEALTH
CITY OF CHICAGO -
DIVISION OF VENTILATION

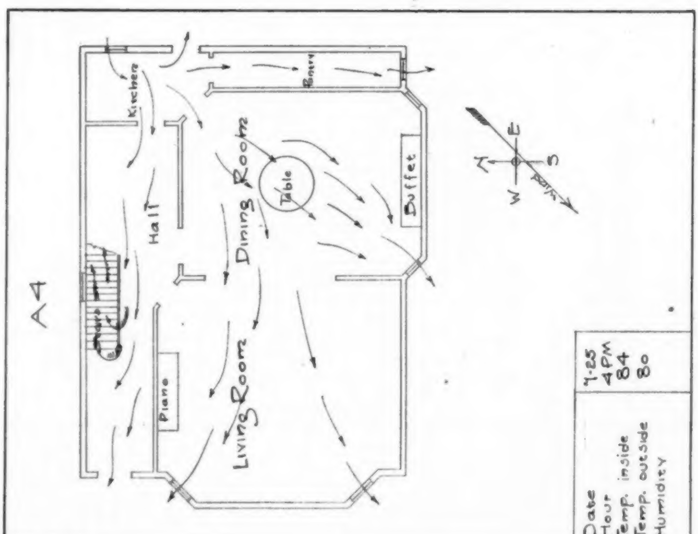
H20.1

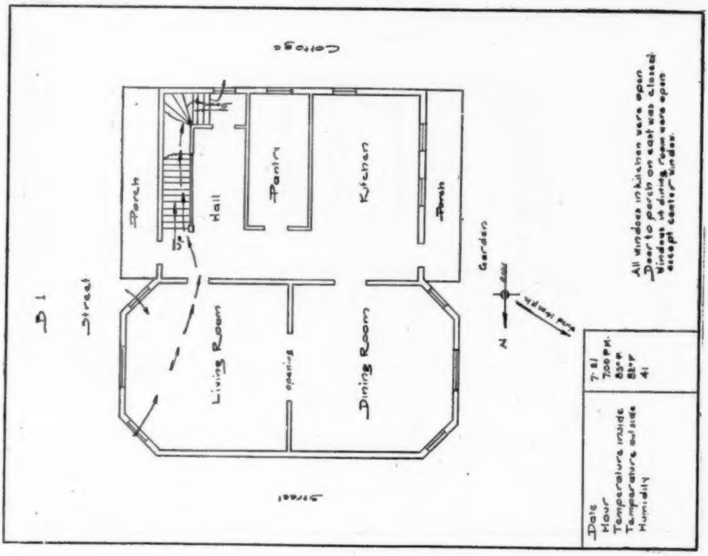

TEMPERATURE AND HUMIDITY CHART
PLOTTED FROM J.W. SHEPHERD'S
TESTS IN THE EXPERIMENTAL ROOM
OF THE CHICAGO NORMAL COLLEGE BY
DR. E.V. HILL
VERY WARM
TOO WARM
ZONE OF COMFORT
R=316-4T
COOL
TOO COLD
75 73 71 69 67 65 63 61 59 57 53
TEMPERATURE
30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66 68 70 72 74 76 78
RELATIVE HUMIDITY
R = 316 - 4T
R = RELATIVE HUMIDITY
T = ANY TEMPERATURE ABOVE 55°
DEPARTMENT OF HEALTH
CITY OF CHICAGO
DIVISION OF VENTILATION
H20.0

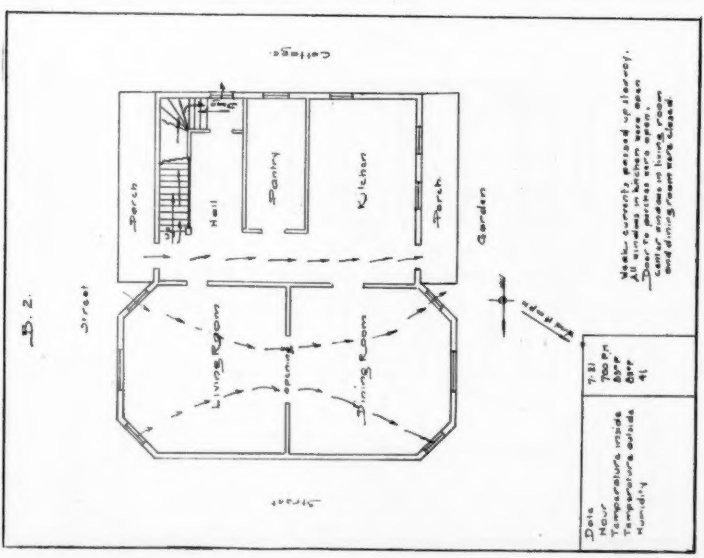

A1
Kitchen
X
A
Pantry
Hall
Dining Room
Table
Buffet
Stairs
Piano
Living Room
N
W
E
S
When door at X was open the strongest current was thru Hall.
When door at X was closed the current was strongest through A passing to Hall and upstairs as with X open
Date 7-26
Hour 2PM
Temp inside 85
Temp outside 86
Humidity 61%

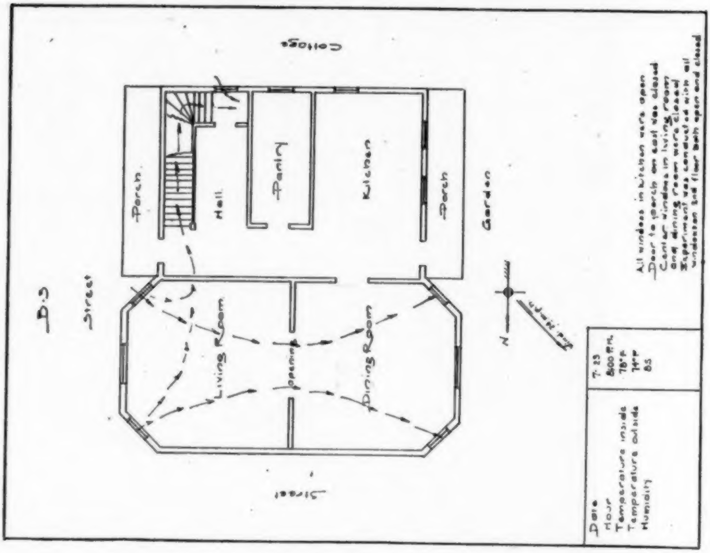

A2
Kitchen
Pantry
Hall
Dining Room
Table
Buffet
Piano
Living Room
N
W
E
S
Date 7-22
Hour 2:30 PM
Temp. inside 89
Temp outside 92
Humidity 50%

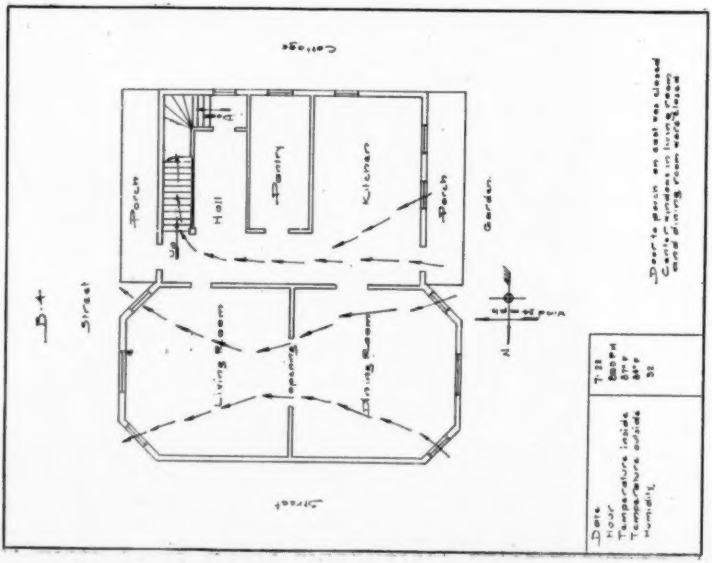

A3
Kitchen
Pantry
Hall
Stairs
Dining Room
Table
Buffet
Living Room
Piano
N
E
S
W
Wind 24 MPH
Date 7-23
Hour 3 PM
Temp. inside 88
Temp. outside 82
Humidity 85%

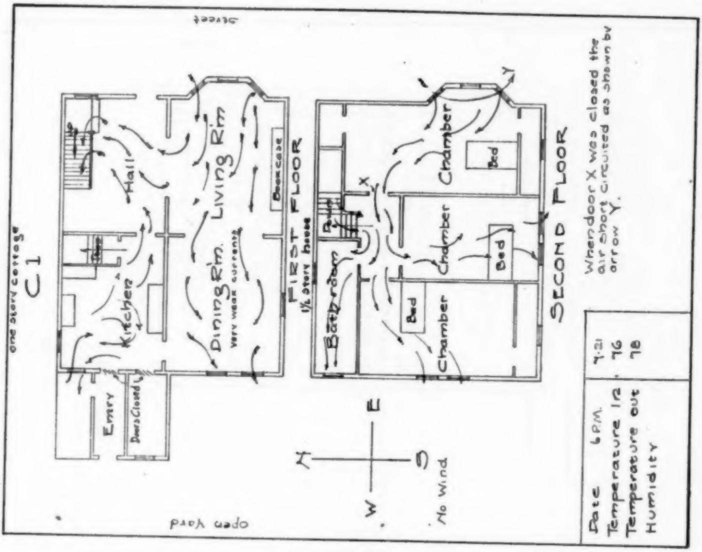

A4
Kitchen
Pantry
Hall
Stairs
Dining Room
Table
Buffet
Living Room
Piano
N
E
S
W
Wind
Date 7-23
Hour 4 PM
Temp. inside 84
Temp. outside 80
Humidity

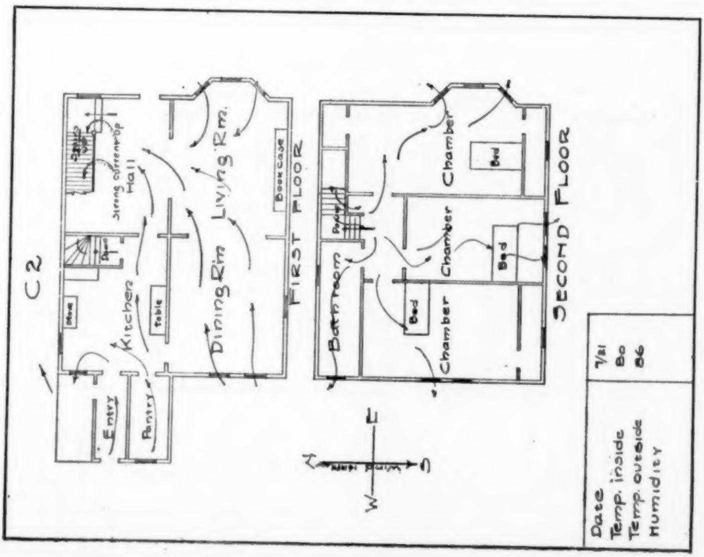

B 1
Street
Cottage
Street
Porch
Hall
Pantry
Kitchen
Porch
Living Room
opening
Dining Room
Garden
N
All windows in kitchen were open
Door to porch on east was closed
Windows in dining room were open
except center window.
Date 7.21
Hour 7.00 P.M.
Temperature inside 83°F.
Temperature outside 83°F
Humidity 41

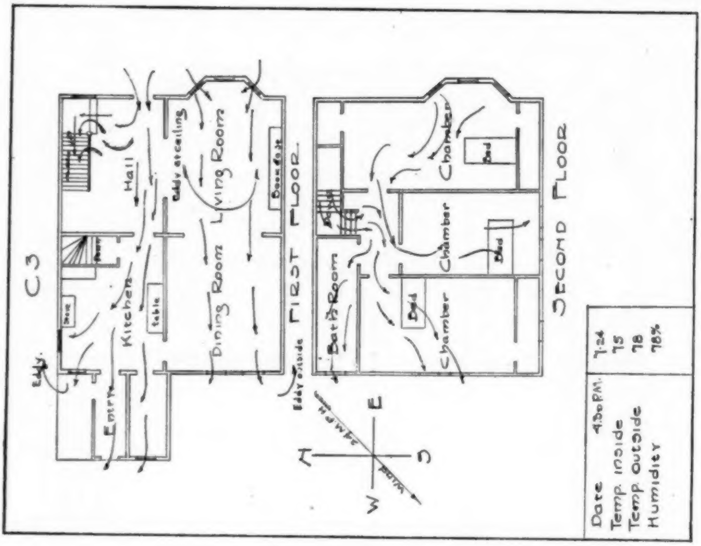

B. 2.
Street
Cottage
Street
Porch
Hall
Pantry
Kitchen
Porch
Living Room
opening
Dining Room
Garden
Weak currents passed up stairway.
All windows in kitchen were open
Door to porches were open.
Center windows in living room
and dining room were closed.
Date 7.21
Hour 7.00 P.M.
Temperature inside 83°F
Temperature outside 83°F
Humidity 41

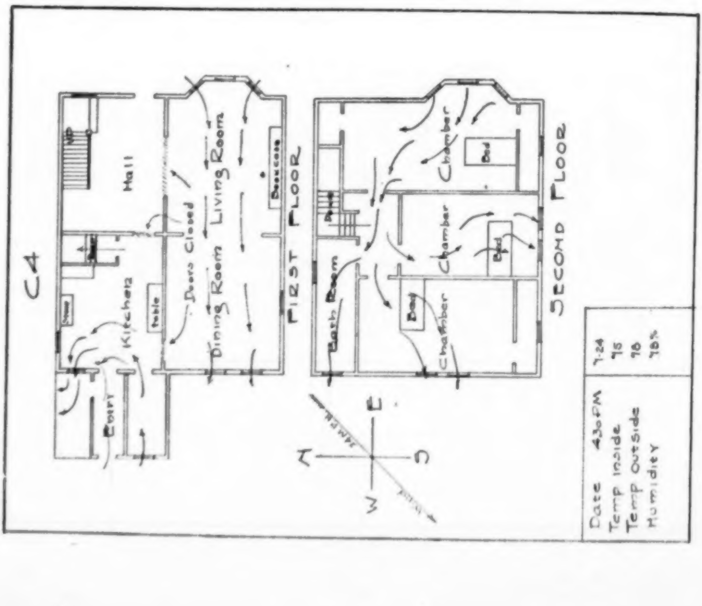

D-3
Street
Cottage
Street
Porch
Hall
Pantry
Kitchen
Porch
Garden
Living Room
Opening
Dining Room
N
Date
Hour
Temperature inside
Temperature outside
Humidity
7-23
8:00 P.M.
78°F
74°F
85
All windows in kitchen were open
Door to porch on east was closed
Center windows in living room and dining room were closed
Experiment was conducted with all windows on 2nd floor both open and closed

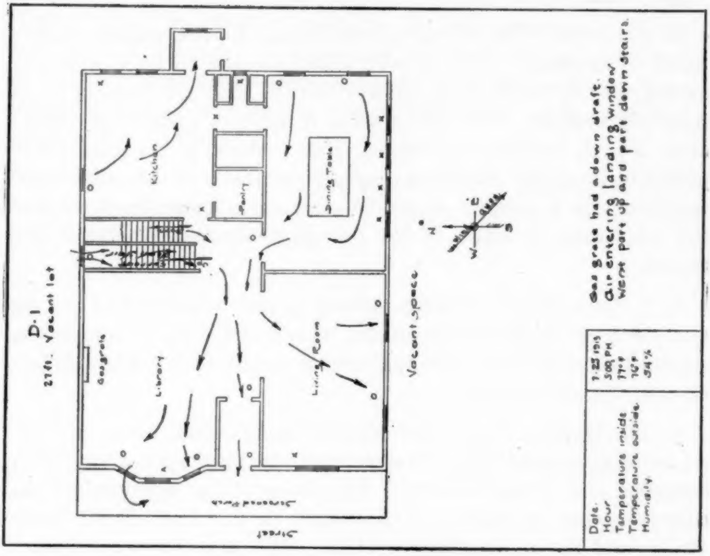

D-4
Street
Cottage
Street
Porch
Hall
Pantry
Kitchen
Porch
Garden
Living Room
Opening
Dining Room
N
Date
Hour
Temperature inside
Temperature outside
Humidity
Door to porch on east was closed
Center windows in living room and dining room were closed

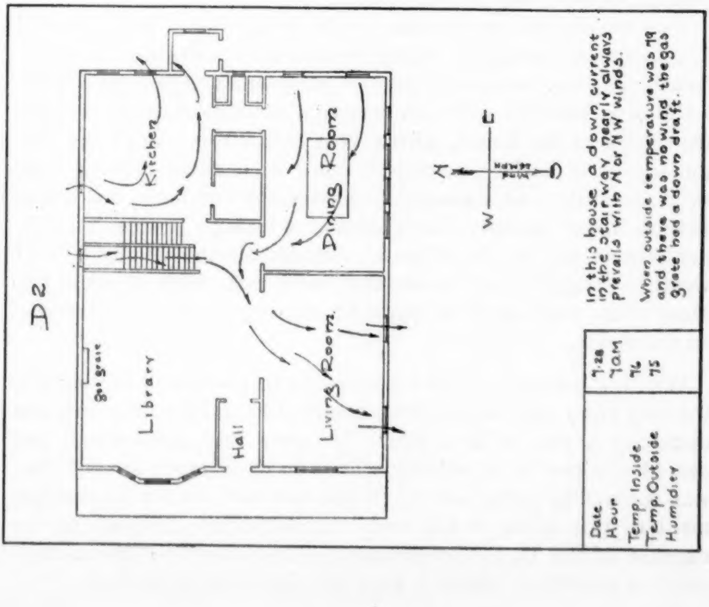

one story cottage
C1
Street
Kitchen
Hall
Living Rm
Dining Rm.
very weak currents
Bookcase
FIRST FLOOR
1½ story house
Entry
Doors Closed
Bathroom
Chamber
Chamber
Chamber
Bed
Bed
Bed
X
Y
SECOND FLOOR
When door X was closed the air short circuited as shown by arrow Y.
W
E
N
S
No Wind
open yard
Date 6 P.M. 7.21
Temperature In 76
Temperature out 78
Humidity


C2
Kitchen
Table
Entry
Pantry
Hall
strong currents up
Dining Rm
Living Rm.
Bookcase
FIRST FLOOR
Bathroom
Chamber
Chamber
Chamber
Bed
Bed
Bed
SECOND FLOOR
W
E
N
S
Date 7/21
Temp. inside 80
Temp. outside 86
Humidity


C3
Hall
Eddy at ceiling
Living Room
Bookcase
Dining Room
Kitchen
table
Stove
Entry
Eddy
Eddy outside
FIRST FLOOR
Bath Room
Chamber
Chamber
Chamber
Chamber
Bed
Bed
Bed
SECOND FLOOR
Wind
E
W
Date 4.30 P.M. 7-24
Temp. inside 75
Temp. outside 78
Humidity 78%


C4
Hall
Living Room
Bookcase
Doors Closed
Dining Room
Kitchen
table
Stove
Entry
FIRST FLOOR
Bath Room
Chamber
Chamber
Chamber
Bed
Bed
Bed
SECOND FLOOR
E
W
Date 4.30 P.M. 7-24
Temp inside 75
Temp outside 78
Humidity 78%


D-1
27 ft. Vacant lot
Gas grate
Library
Living Room
Kitchen
Pantry
Dining Table
Vacant space
Street
Date
Hour
Temperature inside
Temperature outside
Humidity
Gas grate had a down draft.
Air entering landing window
went part up and part down stairs.


D2
Gas grate
Library
Hall
Living Room
Dining Room
Kitchen
Date 7-28
Hour 7 A.M.
Temp. Inside 76
Temp. Outside 75
Humidity
In this house a down current
in the stair way nearly always
prevails with N or NW winds.
When outside temperature was 79
and there was no wind the gas
grate had a down draft.

## DISCUSSION

S. R. LEWIS: The subject of ventilation of living quarters seems to be of moment. This report was intended to be popular in nature, and to serve as an answer to calls that are coming to us from all sources. For this reason it appears somewhat superficial for an engineering report, but I think it contains some points of interest. Before we agreed on many of the points, the conditions in a number of rooms were investigated and we had the testimony of many of the occupants before we signed the report.

A. S. ARMAGNAC: There is nothing to state what kind of heating systems were in use in the houses tested, and while it was in the summer time, if there were registers it might have made a difference in the air currents.

J. H. DAVIS: There are several points that occur to me. At the beginning it states that:—"Our ideal is a spring day, with sunshine and a cool breeze." The thought has occurred to me that the cause of much complaint may be due to artificial ventilation, and the re-breathing of $CO_2$. We have all seen firemen come up from the stoke-hole and put their heads out to get a "breath of fresh aid" as they put it.

The report also states that "with direct steam or hot water . . . . . the air leakage is negligible and the moisture content becomes very low in a short time." Some eight years ago I made a test of a residence where there was a stairway running through the centre of the house, with a vent at the top. With the customary glass surface deducted, there was about 1200 or 1300 sq. ft. of wall. The air current through the ventilator was about 144 cu. ft. per minute, which showed a leakage of over 1 cu. ft. per minute per sq. ft. of wall. Almost all the windows were weather stripped, and those that were not, were chinked up. Most of the walls were the usual 12 in., some were 9 in., plastered on the inside.

WM. J. BALDWIN: In Morin's treatise that was used in France in the very early part of the 19th century, General Morin points out distinctly a case of this kind. He goes into some detail and describes a test of a building where he drew more air out than was apparently going into it. If any one cares to see an abridgement of this work, it has been translated into English at the expense of the U. S. Government. This was done about 1873, and it is possible to obtain it from the Smithsonian Institute.

General Arthur Morin[1] was the first to speak of the use of the "Mixing Valve" in warming buildings. In his *Etudes sur la Ventilation,* 1st Vol., he says: "During the period of artificial warming, it is desirable to preserve means of mixing with the *warm air* of the heating apparatus, *cold air,* the amount of which can be regulated by convenient registers."

S. R. Lewis: In answer to the question, these houses had open windows as the tests were made in July. I do not think that registers affected any of them.

1Director of the Conservatory of Arts & Trades, Paris.

No. 411

# AN OUTLINE OF THE ACTIVITIES OF THE NEW YORK STATE COMMISSION ON VENTILATION FOR THE YEAR 1915

BY GEORGE T. PALMER, NEW YORK

Member

A REVIEW of the first eighteen months' work of the New York State Commission on Ventilation, which body it will be recalled was organized in June, 1913,[1] was presented before this Society in a paper by Mr. D. D. Kimball and the writer at the Annual Meeting in January, 1915.

The efforts of the first year and a half were devoted mainly to a study of the effect on the body of temperature and chemical purity of air. This was the initial step in carrying out the program of determining the relative importance of the different factors in ventilation, namely—temperature, humidity, air motion, chemical composition, odor, dust and bacteria.

During the past year certain of the studies on temperature and stale air have been repeated. In addition to this, studies have been made on (1) the relation of heat and cold to respiratory affections, (2) the influence of humidity on comfort and mental work, (3) methods for determining the dust content of air, (4) the comparative effects of different types of natural and mechanical ventilation on comfort, mental efficiency and physical condition, (5) and the course taken by air currents in a fan ventilated room.

It will be remembered that the early experimental work carried on in the Commission laboratories at the College of the City of New York tended to show that as compared with the chemical

[1]The Commission was appointed at the request of the New York Association for Improving the Condition of the Poor. The Fund of the Commission was provided by Mrs. Elizabeth Milbank Anderson.

Presented at the Annual Meeting of THE AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, New York, January, 1916.

purity of the air, temperature is by far the bigger item in determining comfort in an occupied room. Even slight differences in temperature produce characteristic physiological responses in the body, affect the output of physical work and likewise the inclination to do mental work. In only one respect did the chemical quality of the air breathed show any characteristic effect on the body mechanism, this effect appearing in the slightly diminished appetite for food in a stale, unventilated atmosphere.

During the past year then, it was thought desirable to press this inquiry about air quality still further. If stale, used air is bad, what particular element of the staleness is bad? Is it the odor present? Is it the increased $CO_2$? Are there organic poisons present which dull the appetite?

Believing that the non-existence of organic poisons in respired air has been pretty well demonstrated, the Commission chose to investigate the relative effects of odor and $CO_2$. By ventilating an experimental chamber occupied by five people with fresh air throughout, but introducing at times artificial body odors and at other times an excess of gaseous $CO_2$, it was hoped to identify the bad factor. This effort, however, has not been crowned with success. So long as fresh air was supplied, neither the addition of excess $CO_2$ nor of noticeable, objectionable odors caused any diminution in the food consumption of the subjects. The failure of this test may have been due to the fact that the artificial odor condition did not truly duplicate the condition that would prevail naturally. Again, there remains the possibility that the slight oxygen decrease in a stale air room is responsible for the depression of the appetite. The Commission hopes to look into this question.

One result of the temperature studies and the relation to mental work indicated that for extreme mental concentration involving almost an entire absence of physical exertion, a temperature of 75 degrees at 50 per cent. relative humidity was preferable to 68 degrees at the same humidity, whereas for tasks involving greater motor effort, such as operating a typewriter, the cooler temperature was co-incident with the greater output. During the past year this result has been confirmed, using this time women instead of the young men subjects of the previous study.

As has been mentioned our study of temperature effects has demonstrated certain resulting re-adjustments in the body mechanism. Increased body temperature, increased pulse rate and lowered blood pressure are the effects of over-heating. These changes of body temperature and adjustments of the circulatory

system are no doubt manifestations of the body's effort to reach a state of thermal equilibrium with the outside environment. Another manner in which temperature may affect the body is shown in a four months' study which we have made of the reactions of the nose and throat. Nearly 150 male subjects were observed in this study, including, among others, workers whose occupation in itself was associated with certain distinctive temperatures, such as truck drivers exposed to the varied weather conditions, boiler makers and firemen used to hot, dry atmospheres, and laundry workers who are exposed to heat and humidity or to cold, and at other times they have been shifted tal chamber at times for several hours to extreme heat and humidity or to cold and at other times they have been shifted back and forth from one extreme to the other. Ordinarily it was found that heat causes a swelling of the inferior turbinates of the nose, tending to diminish the size of the breathing space, increased secretion and reddening of the membranes. The action of cold, as a rule, is just the opposite, namely, a reduction in the size of the inferior turbinates, a diminution of secretion and color of the membranes. In the industrial workers, mentioned above, whose occupations involved continued exposure to extremes of heat and cold, these typical changes were not followed. This study was very successful in picturing how the membranes of the nose of such people are less able to make the adaptations of the normal nose to changes in the atmospheric environment. That abnormal conditions of a permanent nature may be produced by repeated exposure to over-heating is suggested by our findings among laundry workers. In this group atrophic rhinitis was thirteen times as prevalent as among young students.

Resistance to infection is another thing which we found to be influenced by temperature. Certain of our animal studies carried on during the year have shown that chilling and overheating do diminish the body's resistance to infection. Rabbits which have been chilled subsequent to inoculation with snuffles bacilli show a higher mortality from the disease than animals similarly inoculated but not chilled. Furthermore, the production of protective substances in the blood, in this particular instance hemolysin and agglutinin, was found to be less in those animals which were kept in an overheated atmosphere than in animals kept in a normal environment.

This fall the humidity question has been looked into. It is the general impression that extreme dryness is productive of

nervousness. We have designed experiments to test out this question and also to see where comfort lies in this humidity scale. A hot, dry school-room condition or 75 deg. fahr. and 20 per cent. relative humidity has been simulated in this work and for comparison humidities ranging between 30, 40 and 50 per cent. have been observed also. Although this work will not have been completed till February, it appears now that the intermediate humidities around 35 per cent. are at least more comfortable than either the extreme dryness or the 50 per cent. humidity which feels quite moist. The effect of dryness in decreasing the steadiness of the hand, the eye or the arm or in causing confusion of mind or distraction, if indicated at all, is very slight. As measured by the saturation deficit the dryness of 20 per cent. humidity at 75 degrees is greater than at 68 degrees, and it is therefore more than probable that dryness at 68 degrees would be even less easily detected if at all.

During the past year also, some little time has been devoted to the dust problem as a ventilation factor. We were handicapped somewhat in this work by the lack of satisfactory devices for collecting and analyzing dust. It was therefore necessary to actually develop a new apparatus for this purpose. An account of this is to be published in the January number of the Journal of the American Public Health Association. By means of this new equipment we have been enabled to determine the dust content of various environments—out of doors, offices, factories, schools, etc. This is but a preliminary step in the interpretation of the general significance of dust as an element in room ventilation.

The past year has further witnessed efforts on the Commission's part to attack the practical working side of ventilation, that is, to determine what methods of ventilation produce the most favorable results. We have now well under way a study of the comparative efficiency of natural ventilation as compared with the more complex mechanical ventilation. To make this more complete observations are also being made of intermediate steps between the two, involving partial natural ventilation and partial use of blowers and ducts.

We wish to find out whether there is an appreciable advantage to comfort in admitting air to a schoolroom directly from open windows.

Also if such an advantage exists, is it of such moment as to influence the physical and mental development of the pupils? If such an advantage appears are there operating and economic dif-

ficulties of such consequence involved as to overbalance this advantage.

To shed light upon these momentous questions, six members of the Commission's staff, all scientifically trained people, are actively engaged in this work. Sixteen occupied schoolrooms in four different schools which present the ventilation variables desired are being subjected to detailed study. It is felt that intensive work of this character is far more valuable than the collection of data at random from a much larger number of rooms. One phase of this study demands the entire attention of two observers within the schoolroom throughout the day. An entire week is thus spent on a single room at a stretch and the same room is re-visited in the same careful manner in the different seasons—fall, winter and spring. Observations are made of temperature in different parts of the room, relative humidity, air supply, air movement, carbon dioxide content, deheating effect of the air, together with notes on the ventilation methods at the time including extent of window and door openings, population of the room, etc. In this connection it has seemed feasible to express certain factors in terms of the actual number of pounds of living matter present rather than by the number of people present. Square feet of floor space per 100 pounds of flesh is a much more instructive figure than square feet of floor space per person. Heat and respired air output vary closely with a person's weight. The average child of the first grade weighs 49 pounds whereas the eighth grade pupils weigh 100 pounds.

Another most necessary feature in studying ventilation in practice is to observe along with the indoor factors the air conditions out of doors. We have endeavored to make our work complete in this respect by taking records on the roof of the school building at stated intervals during the day, of temperature in the shade and in the sun, relative humidity, wind direction, wind velocity, barometric pressure and of the general weather manifestations not included in the above.

Of great assistance in carrying out this study are the two specially equipped schoolrooms in one of the city schools which were touched upon briefly at last year's meeting. These rooms are ventilated by two separate and distinct plants in the basement, these being under the personal supervision of an engineer on our staff. Time will permit only the briefest mention of this most elaborate equipment which includes heaters located at several different points in the system, air washers, plenum and exhaust fans,

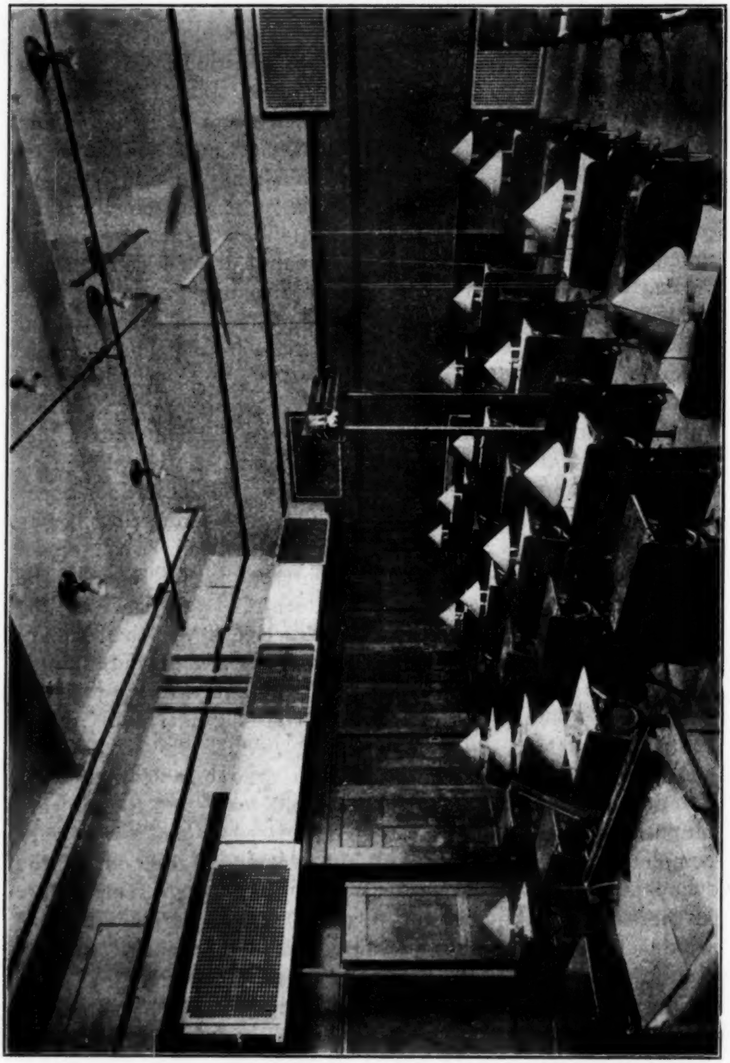


FIG. 1. PHOTOGRAPH OF SCHOOLROOM SHOWING OVER-HEAD TRACKWORK AND TRAVELING CRANE FOR AIR CURRENT MEASUREMENT.

The cross-bar and paper flags are seen suspended at the further end of the room. On the desk tops, under metal cones, are lighted candles which produce the same amount of heat as a classroom of children would emit.

complete thermostatic control of the heating and humidifying units, and sufficient ducts and branches to permit of admission and extraction of air at different points in the room. One room is provided with individual inlets in the floor beneath each desk

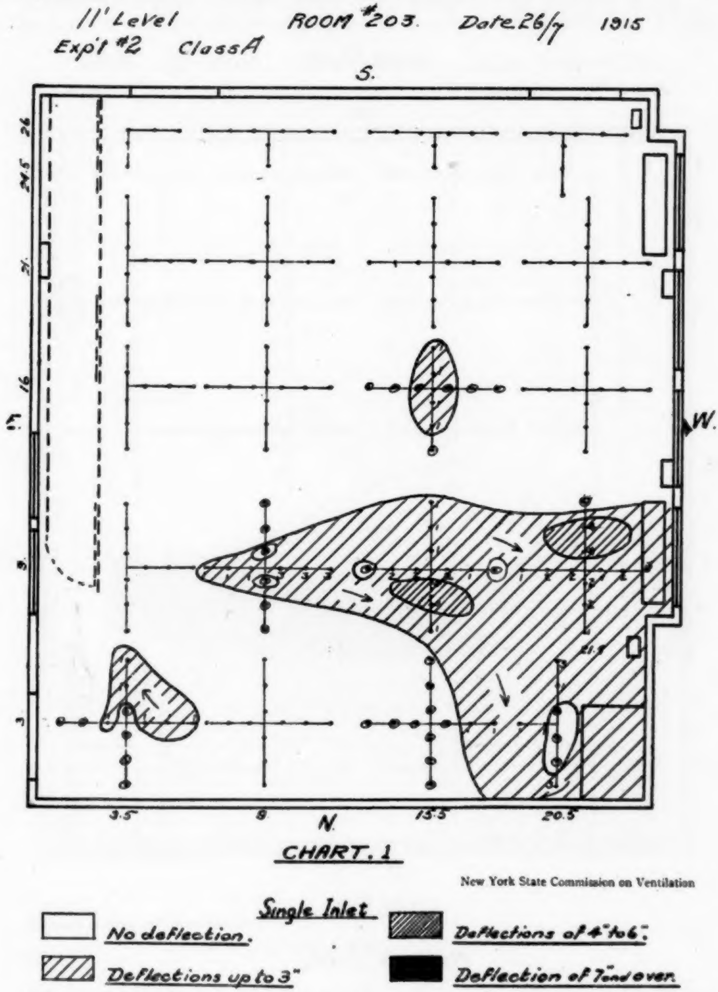



CHART. 1

New York State Commission on Ventilation

and several outlet registers in the ceiling. The other room has eight wall registers located at different positions on two adjacent walls. Provision has been made in the basement for measurement of steam, electricity and water consumed.

Another study of more strictly mechanical nature and perhaps of greater direct interest to members of this Society has been a survey of the air currents in a room with different points of admission of the incoming and outgoing air. The tracing of slight air currents has been usually accomplished by means of

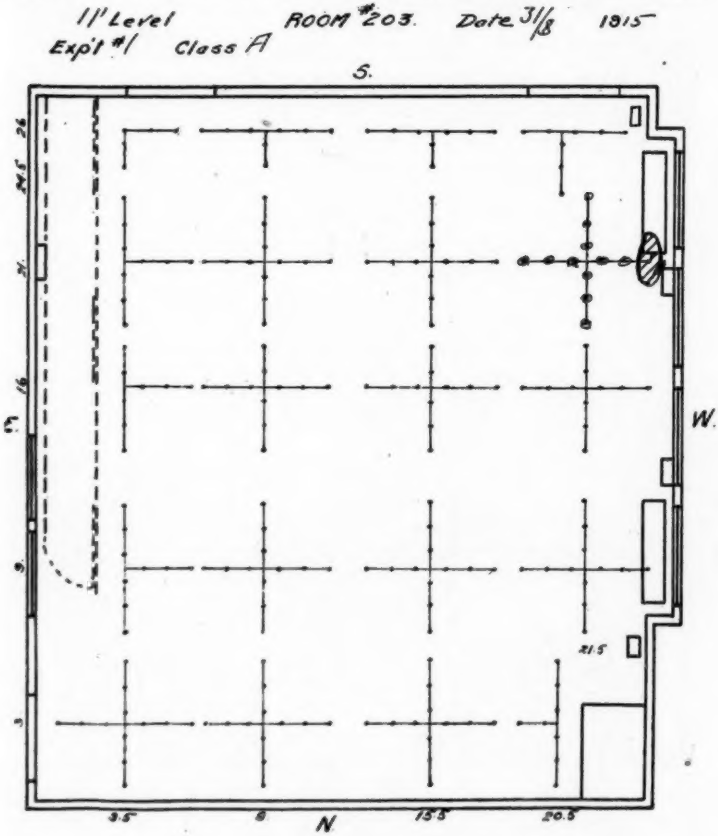



CHART 2

New York State Commission on Ventilation.

*Multiple Inlets*

smoke, balloons, ammonium chloride, hydrogen sulphide and so forth. While these indicators are of value, it is difficult to reproduce graphically the results of such tests. To meet this objection we have made use of a small tissue paper flag suspended on a silk thread. Air currents even as slight as five feet per

inlets, nine feet from the floor, with two outlets on the adjacent deflection in inches away from the perpendicular can be read easily with the eye.

The schoolroom in which we have made these surveys is pro

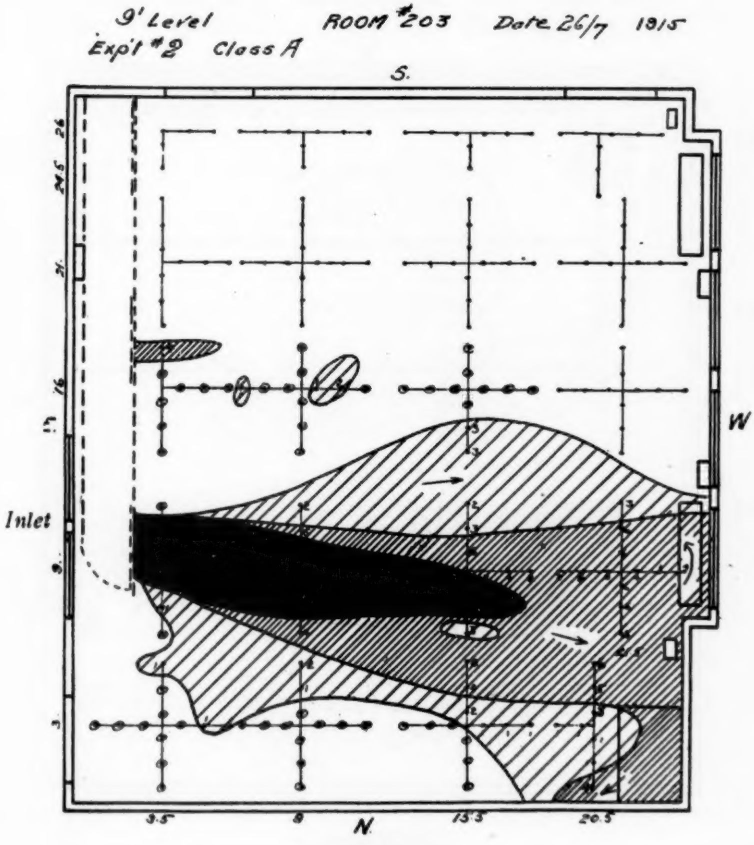



CHART 3
Single Inlet.

New York State Commission on Ventilation

vided at the ceiling with a traveling crane (see Fig. 1). To this crane is suspended at its intersection a cross-bar, each stick being five feet in length. On this cross-bar are hung at one foot intervals the silk threads, one foot in length with the paper flags one inch square.

With this apparatus guided by ropes and pulleys, we have been able to make a fairly complete survey of the room. For convenience the room has been marked off into five horizontal planes, 3 inches from the floor, 3 feet, 6 feet, 9 feet and 11 feet,

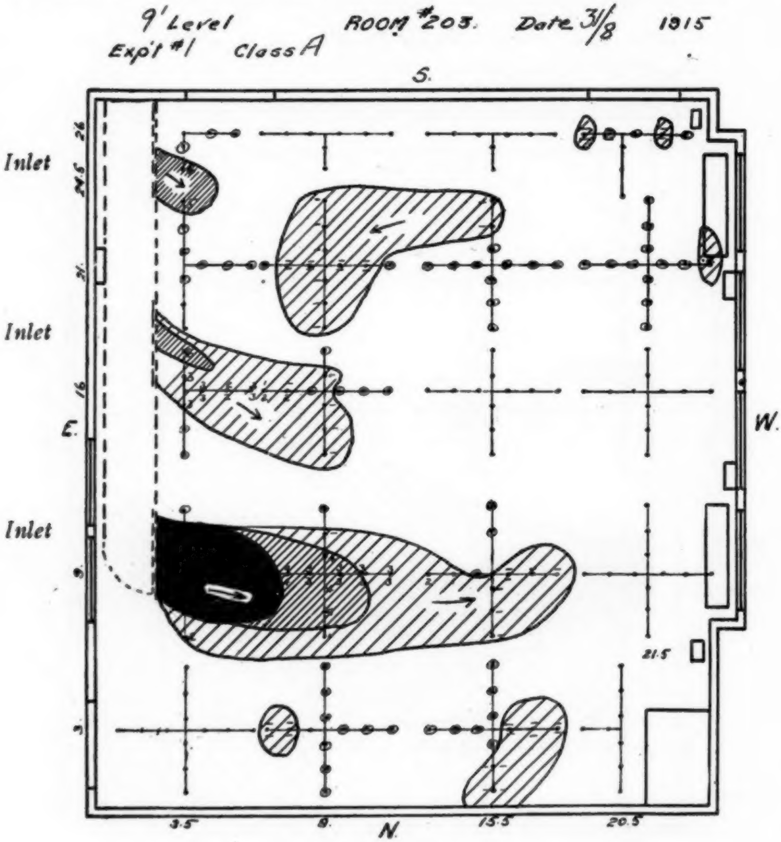



CHART. 4.

New York State Commission on Ventilation

Multiple Inlets.

the room being 14 feet in height. Each plane is then divided into squares of approximately six feet on a side. The cross-bar is then set at the intersecting lines of these squares and by shifting the cross-bar over twenty different positions the area of the horizontal plane, 24 feet by 27 feet, is covered.

A survey is made by two observers, one manipulating the guide ropes and reading the east and west deflections of the flags and the other observer reading the north and south deflections and keeping the notes. Deflections are thus noted at 206 different

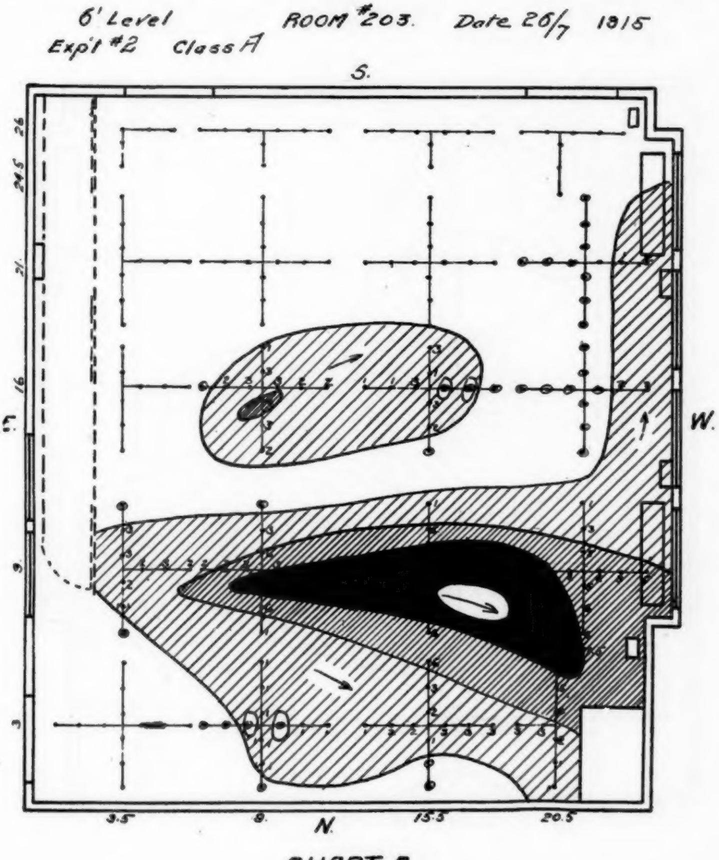



CHART. 5.

Single Inlet.

points in each horizontal plane. This makes a total of 1,030 readings for the five planes in the room.

It is possible here to show you only a few of these records in graphic form. In Charts 1 to 10 is pictured the distribution of air currents in a room ventilated in the one case through three

inlets nine feet from the floor with two outlets on the adjacent wall at the floor, and in the second case, with a single inlet on the side wall nine feet from the floor and the outlet on the floor on the farther end of the adjacent wall.

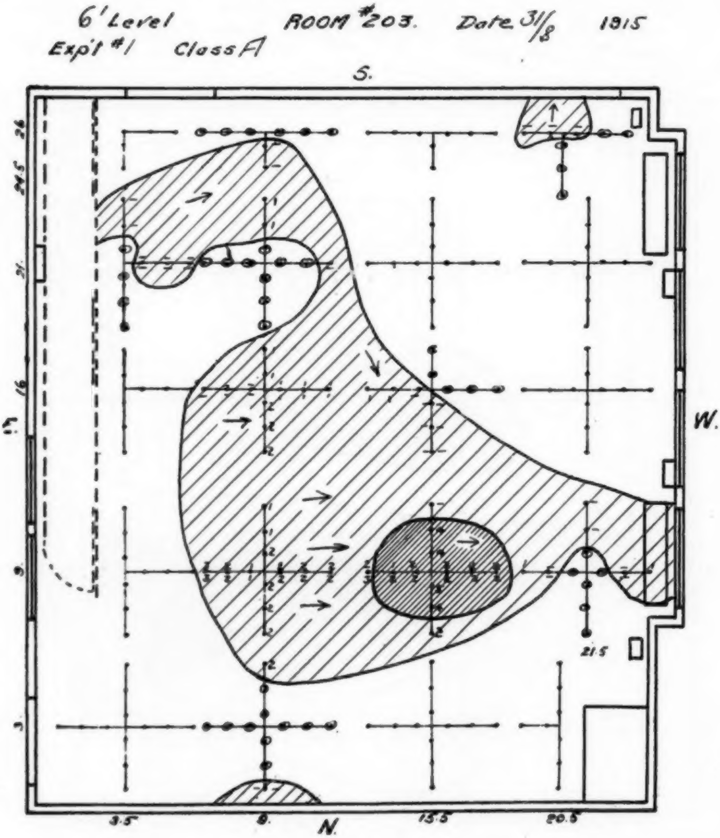



CHART 6.

New York State Commission on Ventilation

Multiple Inlets.

In Charts 1 and 2 is shown the movement in the horizontal plane 11 feet from the floor for both types of distribution. The higher velocity from the single inlet produces air movement at the ceiling whereas there is none to speak of in the multiple inlet room.

In Charts 3 and 4 showing the 9-foot level, the movement is more concentrated in the former. The movement from the three inlets is indicated in Chart 4.

In the 6-foot level shown in Charts 5 and 6 the single inlet

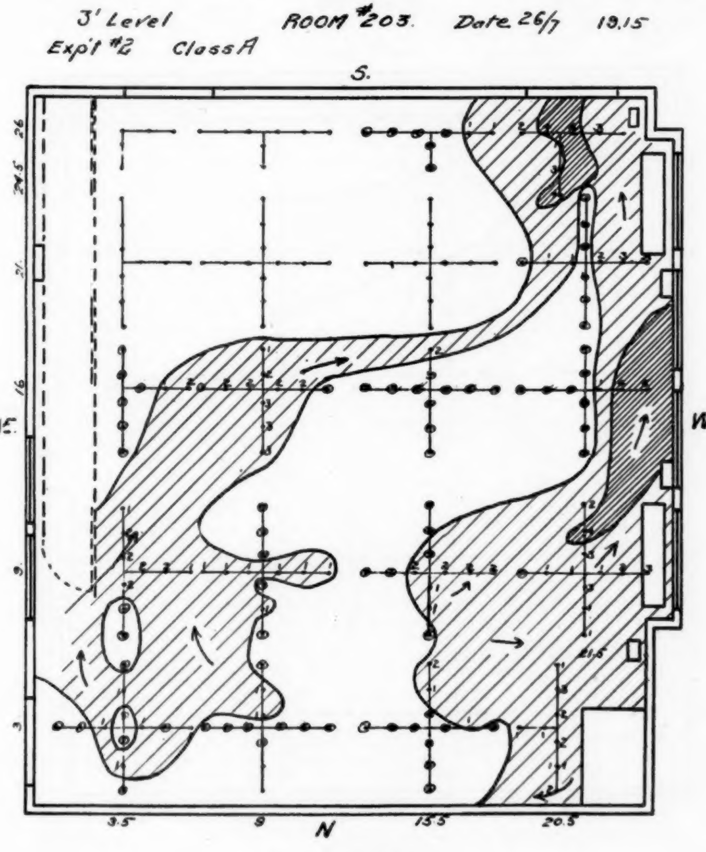



CHART 7.

Single Inlet.

New York State Commission on Ventilation

still confines the air current to a fairly narrow region, with appreciable velocity, whereas the air in the other figure shows a tendency to spread about somewhat.

In Charts 7, 8, 9 and 10, the velocity of the current from the multiple inlets has largely spent itself in crossing the room,

whereas the high velocity from the single inlet has caused movement in the reverse direction at the floor level, sufficient to form a well defined stream diagonally across the room to the floor outlet.

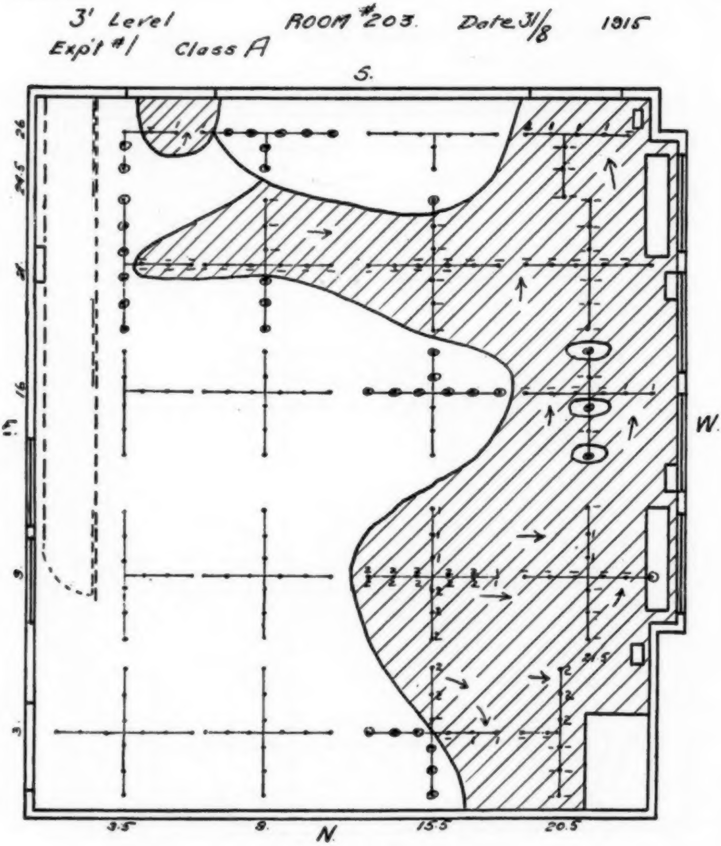



CHART. 8.

New York State Commission on Ventilation

Multiple Inlets.

In connection with this comparison of number of inlets and thoroughness of air distribution it is of interest to mention that in an adjoining room to the one described there are individual inlets beneath each desk or nearly 50 in all. There are six outlets spread over the ceiling. The circulation of air through this

room is at such slight velocity as barely to deflect the flags at all. To detect these vertical currents the paper flag was suspended within a box open at the diagonal corners. Vertical currents deflect the flag horizontally in passing through this box.

The above records were made last summer when the conditions indoors and out of doors were nearly identical as to tem-

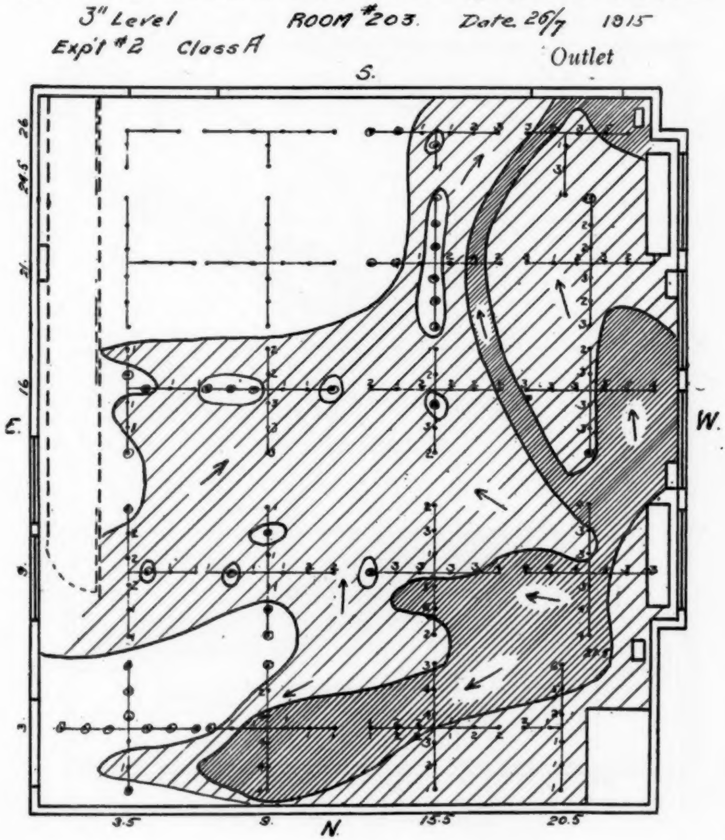



CHART 9 — SINGLE INLET

perature. A repetition of this work in the colder weather has brought out some very interesting changes in air currents due to the difference in temperature between the air of the room and the entering air. If we take a longitudinal section of the room directly in front of the air inlet and plot the deflections for the different horizontal planes in that particular vertical plane, we

get the characteristic result shown in Chart 11. Here the warm air entering a cold room immediately rises to the ceiling with an appreciable velocity. In the other case the entering air being cooler drops to the floor in its course across the room.

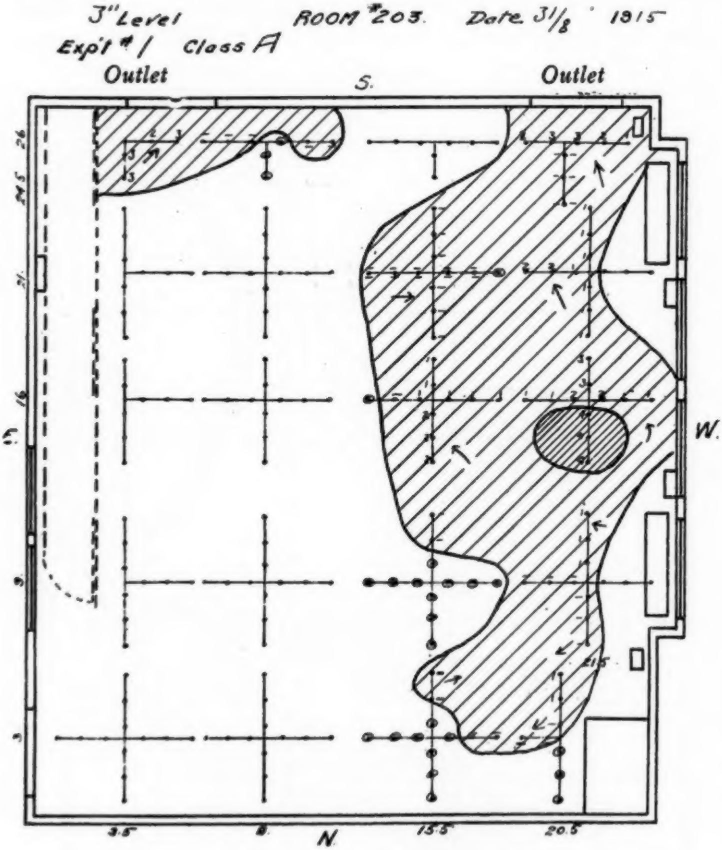



CHART 10—MULTIPLE INLETS

There is a vast amount of charting to be done before this study can be fully interpreted. I have endeavored, however, in this brief description to explain the apparatus employed and the manner in which the data thus arrived at is open to graphical treatment.

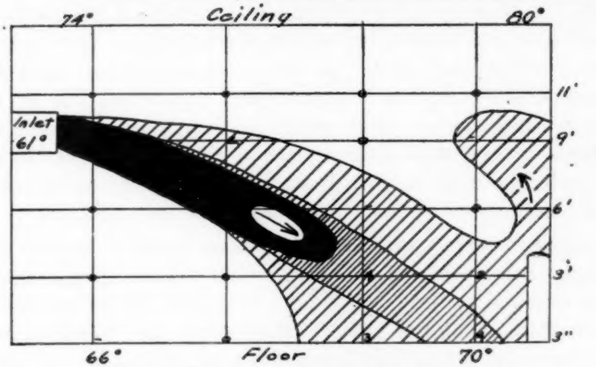
It is customary in describing the nature and outcome of experimental work to summarize with certain definite conclusions.

However, as much of the work is being repeated for verification and as new lines are taken up, the results of which may influence the interpretation of preceding efforts, and as much of the

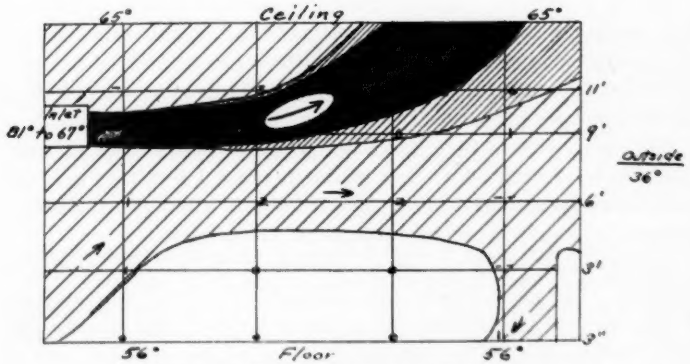
CHART 11

Direction taken by warm and cold streams of air entering a room.

This is a vertical section of the room directly in front of inlet. Temperatures (Fahr.) are noted at different points.




ENTERING AIR COLDER THAN ROOM AIR.




ENTERING AIR WARMER THAN ROOM AIR.

work herein touched upon is in progress, no broad conclusions are here presented. I have confined my remarks to a description of the various kinds of work in which the Commission has been engaged during the past year, outlining the avenues of approach to the various ventilation problems under investigation.

## DISCUSSION

M. W. FRANKLIN: This paper emphasizes one potent aspect of the art of heating and ventilating, at the present time. The opinion is unanimous that hitherto engineers have devoted their attention to the standardization of apparatus and the question as to what constitutes good ventilation has been accorded scant attention, so we know less about ventilation than we do about applying methods of obtaining it. Engineers have looked to the medical profession to tell them what was needed for adequate ventilation. The engineer was able to supply any amount of air at any temperature or degree of humidity, and with any air movement demanded, but he had little information as to what would constitute good ventilation. The medical profession is the last place in the world to look for this and it seems the most natural thing that not doctors but a special commission should be appointed to make these investigations.

We should co-operate with this Commission in every way, for they are dealing with a phase of our work which has been neglected and which is essential to the whole work. I should like to see greatly extended efforts along this line. If the Society can co-operate with this committee, it will be furthering the cause of heating and ventilating in general, and will be of more potent benefit to the profession than the mere standardization of apparatus.

DR. E. V. HILL: The first thing that occurs to me is as to what they are going to compare their results with. What standards are they going to adopt in checking up their information? When you have data to compare, you must have standards, for without them comparisons are impossible.

The square feet of floor space per pound of flesh is an extremely good point. I shall adopt that myself because I find that it is unsatisfactory in making tests in schoolrooms to count the number of persons, who vary in weight throughout the grades.

Another point is, in testing air currents: We have used various methods. The most satisfactory, although one of the most difficult to use, was the toy balloon, but it was not easy to get enough balloons in operation at the same time. Now we are working with an apparatus that pumps air through a soap solution, and blows about 50 bubbles at a time. This is not entirely satisfactory, as some of the bubbles break, but I hope to be able to solve the problem.

PROF. WM. KENT: In watching that cross-bar with the paper flags, it would seem that it does not tell all the facts—it tells the horizontal air movement, but not the vertical movement. The diagrams, too,

indicate a very much smaller air movement than there really is. In watching smoke, I have seen that the vertical air movement is really greater than the horizontal, and so I have invented a new apparatus which I present to Mr. Palmer for his work.

Referring to Fig. 2, *A* is a hollow rod 10 ft. or more high, according to the height of the room, that has a base, *B*, by which it may be kept in a vertical position. *CC* are small, wide-mouthed bottles or flasks, partly filled with dilute hydrochloric acid, and attached to the rod at intervals of 2 or 3 ft. Each flask has a cover

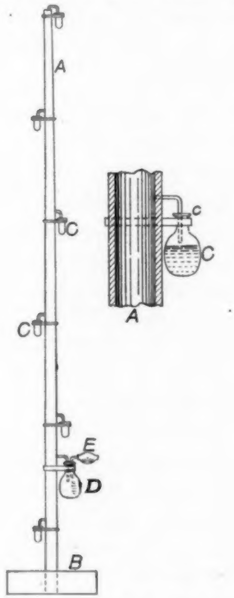



FIG. 2. APPARATUS SUGGESTED FOR A SMOKE TEST OF VENTILATION.

of light cardboard and a glass tube leading from the interior of the rod to near the level of the acid in the flask, and passing loosely through a hole in the cover. *D* is a bottle half-full of ammonia liquid, and *E* is a rubber bulb bellows by means of which puffs of air may be blown into the ammonia, and the air saturated with ammonia vapor driven into the rod and into all the flasks containing acid. White clouds of ammonia chloride will be formed in the flasks and pass from them into the room where they will indicate the direction and the velocity of the air currents. Two or more flash-light photographs, taken at intervals of one or two seconds may also be used to record the direction, velocity and shape of the clouds.

H. M. HART: I should like to ask about exhausting the air. The charts show only the inlet; was there any exhaust, and where were the openings located?

F. G. McCANN: In connection with the tests made, it is apparent that the room inlet and outlet have been taken in unusual relative locations. The common practice, or rather our practice, is to have both the inlet and outlet on the same side of the room.

The two sections in Chart 11 nicely show the fault of having the outlets at nearly opposite points, as there are dead spaces in both cases. I should like to know if any tests have been made with inlet and outlet on the same side, and with direct radiators in service to show a change in air movement.

THE AUTHOR: The first question, that from Dr. Hill, relative to how we propose to study different methods of ventilation, what use we shall make of our observations, and just what shall be our basis for interpreting good ventilation, is answered in a way, by the sentence on page 358, of the report, as follows:

"The past year has further witnessed efforts on the Commission's part to *attack* the practical working side of ventilation . . ."

We are now just attacking the subject. From the data we are gathering and the experiences we are having, we shall expect later on to make use of the points of our attack. We can tell now how we are studying the question, but how we shall make use of our observations, or what shall be our basis for interpreting good ventilation, we are not at this stage prepared to answer.

We are studying the question by gathering data in occupied schoolrooms on temperature, humidity, odor, carbon dioxide, air supply, etc. Not only are we making casual observations from day to day, but we are staying in the schoolroom the whole day, thus noting the changes that take place during the day.

I say we are gathering data on temperature, etc., and this includes reading instruments as well as reading our feelings. In asking what shall be our basis for interpreting good ventilation, Dr. Hill probably has this in mind: Shall we be guided by the readings of our instruments, having in mind the commonly accepted standards, or shall we be guided rather by our *opinions* as to how the air feels? We do not know yet. We are first gathering data in these two different ways and correlating the results. We want to know first what certain readings of the instruments signify in terms of comfort.

We register our *opinions* of the air condition by voting in a graduated scale. Thus we state how the temperature feels in terms of the following numerical scale: 50, too hot; 40, too warm;

30, O. K.; 20, too cool; 10, too cold. In the same way our observers vote on air motion, moisture and odor. They state whether the air feels particularly dead, O. K., or breezy or drafty. We can't give out a temperature standard in terms of personal feeling, but once these feelings are interpreted in terms of physical measurements, then we can express the standard in a more tangible form.

Of course, we realize that people's opinions differ widely and therefore what a single person feels may not altogether be relied on. However, when this same person is making observations day after day, we feel that his opinions for the purpose of comparing different rooms at least are of value.

As to the question of vertical air movement, it is true that these flags as they stand here do not show the exact vertical movement, but they do give an idea of the vertical tendency. It is also true that they do not tell all the air movement, as there is, of course, some air movement taking place that is below the sensitiveness of these particular indicators. Of course, smoke does give the resultant of the horizontal and vertical currents but one objection to smoke is that it is warm and will rise of its own accord and hence indicate a movement that is not a result of differences in air pressure.

In regard to the location of exhaust fans, these are shown in Charts 9 and 10. In Chart 9, while the exhaust fan is not indicated, it is suggested by the air leaving at the right hand upper corner. Chart 10 suggests that there are two outlets, one on either side of the room, at the floor level.

The question about trying direct radiating surface might be answered by saying that this was done in the test shown on Chart 11, where the entering air was cooler than the room air, the room being heated by direct radiation. In the other case, the room was heated by indirect radiation.

Yes, we have studied air currents when the air entered and left the same side of the room. In fact, we have studied eight distinct arrangements of inlet and outlet, and have also varied the temperatures of the incoming air. I have not attempted here to go into the results of these studies but have merely attempted to indicate our method of studying.

## No. 412

# CAN WE STANDARDIZE THE REQUIREMENTS FOR VENTILATION?


By J. J. Blackmore, New York

**Member**


THE question of what constitutes adequate ventilation has been one of great concern to engineers who are called upon to specify the amount and condition of the air needed for ventilating and to determine how the air for this purpose should be taken into and distributed throughout a building.

There are so many factors to be considered and there has been so much opposition to some forms of artificial ventilation that it is not surprising that the engineer has some doubts as to the accuracy of our present understanding of the subject, especially when he is confronted with the statement of some physician who has had a large hospital practice "that air taken over steam-heated coils is not so beneficial for patients as air coming in by open windows."

There is further the almost universal advice of physicians to their patients, "keep out of doors all you can."

There certainly must be some grounds for these statements, and the fact must be accepted that we do not as yet know just what it is that makes outer air conditions so much better than they seem to be in our homes and buildings.

With a view to bringing together all the known factors that must be considered in dealing with this subject, the author will begin by describing the properties in the air as found in the open country and contrast them with the conditions as found in our cities and as they are known to exist in the buildings in which we spend the greater part of our lives, a large majority of such buildings being without special means for ventilation.

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Presented at the Annual Meeting of The American Society of Heating and Ventilating Engineers, New York, January, 1916.

### THE ATMOSPHERE

We will first consider the constituents of the atmosphere and how they are utilized in respiration—what effect respiration has upon the body and to what extent the expired air has been changed by respiration. We have also to consider the effect of the combustion of fuel in the air where great quantities are burned as in our large cities.

The constituents of the atmosphere in the open country average as follows, the various constituents given being the quantities found in ten thousand parts of atmospheric air:[1]

| | | | |
|---|---|---|---|
| Nitrogen | 7,711.60 | Carbon dioxide | 3.36 |
| Oxygen | 2,065.94 | Ozone | 0.015 |
| Vapor | 140.00 | Nitric Acid | 0.08 |
| Argon (about) | 79.00 | Ammonia | 0.005 |

The author quotes this authority because it gives the quantity of each in ten thousand parts of air. Other authorities may differ slightly as to the quantity of some of these constituents, but the differences will not be greater than would be found in samples of air taken at different times or at different places on the earth's surface.

Taking these constituents in the order they are given, nitrogen need scarcely be considered, as its only use or function seems to be to dilute the oxygen to prevent it from becoming too active in the work of combustion.

The next constituent, oxygen, is the life-giving substance in the air, without which animal life, as we know it, would be impossible. Hence we must accept the fact that oxygen is the most important constituent of the atmosphere.

The next constituent, vapor, though by comparison with nitrogen or oxygen is very small, is nevertheless of vital importance to animal life, for while it may not be actually necessary to the process of respiration, man's body is largely composed of water which is constantly evaporating, due to the process of combustion.

Man gives off moisture in three ways, by respiration, by perspiration and emanations from the pores of the skin and through the bladder.

The next constituent, argon, is an inert gas and so far as now known does not effect the process of respiration.

The next constituent, carbon dioxide ($CO_2$) is a familiar one to heating and ventilating engineers, from the fact that its pres-

ence is used to determine the relative purity of the air in our buildings. By its presence the chemist or engineer can determine the amount of air that has come into a room by leakage or otherwise, when it is known how many people have occupied a room for a definite time.

In cities $CO_2$ is present in a slightly larger quantity than in the open country, four parts in ten thousand being the amount usually contained in city air.

Almost all authorities agree that this gas is harmless in the quantities usually found in the air, and Dr. T. R. Crowder[2] shows that its presence is necessary and that up to a certain extent its presence is beneficial. That it is a dangerous and very obnoxious gas when present in large volume can be ascertained by any one who inhales it in the products of combustion coming from a chimney.

The next substance in order is ozone, of which the quantity is so small that its influence on animal life is hard to trace, but this substance, which can easily be produced by electricity, may have a useful place in the art of ventilation for the destruction or elimination of objectionable odors.

The last two constituents, nitric acid and ammonia, do not appear to be of direct use to animal life, but are absorbed by the earth for use of vegetation.

## ARTIFICIAL CONDITIONS

The concentration of man in certain places on the earth's surface favorably located for defence or trade led up to the building of our cities. In the growth of these cities artificial conditions have been created that are detrimental to the physical well being of animal life. This fact is noticed in the increase of $CO_2$ of the air of our cities as compared with that found in the country. It is true this difference is small and does not materially affect the value of the city air for respiration.

The presence of dust, bacteria and odors is very much more evident in the cities than in the country and the fact needs careful consideration in dealing with the subject of ventilation.

In the erection of buildings for shelter and other purposes man has created artificial conditions to a greater extent than he has realized, and it is these conditions, in so far as they concern the air and temperature, that the author proposes to compare with the conditions as found outside our buildings in the open air.

Mr. Ohmes says,[3] "To supply buildings with fresh air is becoming a more difficult problem in our large cities. Not only

are the conditions within the buildings, due to their ever increasing size made more difficult, but the sources from which fresh air may be secured are getting less and less. To emphasize this point, consider for instance, the oil-and-gasolene charged atmosphere created by thousands of automobiles in some of our streets—particularly of our finest streets, viz.: Fifth Avenue, on a typical winter day. But this is not the only contamination that the city air is subject to, for the smoke stacks of large heating and power plants belch objectionable gases and cinders (smoke is prohibited by ordinance in all large cities); there are the torn-up streets with the disagreeable sewer and gas smells. On dry, windy days, we have the dust and dirt from building operations, horse-manure, etc. If it is questionable that the air is healthy at certain times in our streets, what must it be under these conditions in our buildings?"

According to Wolpert,[3] a grown-up man gives out per hour, when sleeping, 0.45 cu. ft. of carbonic acid gas and about 630 grains of vapor. When resting, 0.63 cu. ft. of carbonic acid gas and about 1,080 grains of vapor are given out per hour by the same person; with hard work this is still further increased 1.4 to 2.0 cu. ft. of carbonic acid gas per hour and to 1,490 to 1,760 grains of moisture; all at a temperature of about 71 deg. fahr., and the air at 60 to 70 per cent. humidity. The temperature of the exhaled air is 97 to 99 deg. fahr., and is saturated with humidity. One cu. ft. contains 18.67 grains of moisture at a temperature of 98 deg., so that a man on the average gives out within 24 hours, in this way, 6,520 grains, equal to 0.93 pounds of water.

Ordinarily it is figured that a grown-up person gives out per hour, when resting, 0.7 cu. ft. of carbonic acid gas and 1,110 grains of moisture, and when working hard, 1.4 cu. ft. of carbonic acid gas and 1,500 grains of vapor. For a child, one-half may be figured. Air containing 8 per cent. (by volume) of carbonic acid gas (800 parts in 10,000), according to time limit, gives headaches, nervousness and slow death, but the same actions take place in the air at 4 per cent. (by volume) of carbonic acid gas (400 parts in 10,000), if the carbonic acid gas has replaced a similar amount of oxygen. It will be noted that in the latter case air would almost be the same in oxygen as the air exhaled by a human being.

The heat generated by people is different for both age and sex. A young man will give off more than a young woman, and a man more than a woman. According to Rubner,

a grown-up middle weight man will give out 480 B.t.u. per hour, of which about 400 B.t.u. are measurable, and the rest are used up in vapor generation. Rubner figures that 44 per cent. is given out by radiation, 31 per cent. is lost by conduction and the rest is used up for vapor generation. On the average it can be figured that adults give out 400 B.t.u. per hour, children 200 B.t.u. per hour, and a baby 64 B.t.u. per hour at a temperature of 64 to 68 deg. F.

While the above products of respiration, etc., are unavoidable from any human being, there may be in addition to these, nauseating odors given out due to disarrangement of the stomach, unclean teeth, general lack of cleanliness, etc. Furthermore, odors are frequently given out by certain new floorings, carpets, etc., and often an otherwise well-ventilated room has been criticized on account of odors from these sources.

Dr. T. R. Crowder says,[2] "The air which surrounds the body has two principal functions; a chemical and a physical. It oxygenates the blood and it removes the body heat. For the performance of its chemical function it must contain a sufficient amount of oxygen to keep the hemoglobin saturated and be free from poisonous gases; for the performance of its physical function it must be cool enough to absorb the heat of the body, dry enough to take up moisture from the skin, and have motion enough to carry away the aerial envelope to which this heat and moisture are transmitted. If the air of the room is not renewed its oxygen is gradually consumed and it becomes laden with heat and moisture from the bodies of the occupants. In this way it may finally become unable to perform either of its principal functions. A constant supply of fresh air is therefore necessary.

But careful experiment has demonstrated that under all ordinary circumstances the fault develops on the physical side so far in advance of the chemical that the latter may be practically left out of consideration. Relatively small amounts of fresh air will always supply the chemical needs of the body; large amounts may be necessary to supply the physical demands. Granted that the small amount of air necessary for the demands of respiration is supplied, the control of its physical properties temperature is vastly the most important. The success of ventilation depends far more on supplying conditions suited to the outside of the body than to the inside of the lungs."

The art of ventilation calls for several operations beyond that of conveying into a building a quantity of fresh air and the

removal of a similar quantity of (so-called) foul air from the same building.

The engineer can furnish means to move the air into and out of a building with precision if he is not hampered by an appropriation too small for the work and is given ample space in the building in which to place the apparatus; hence the author considers it unnecessary to go into this part of the problem for it has been ably dealt with by Messrs. Busey, Carrier, Harding and others, in the Transactions of the Society.

The other operations necessary to good ventilation may be designated as follows:

*First:*

Air Cleansing—

(a) The removal of dust and particles from the air before the air enters the heating chamber.

(b) Means for removal of bacteria if such should be found necessary.

*Second:*

Relative Humidity—

(a) Furnishing means to add or deduct moisture to or from the air when the condition of the air needs such treatment.

(b) To furnish adequate regulation that the humidity may be controlled within certain limits that may be found desirable.

*Third:*

Temperature—

(a) To furnish temperature regulation to control the heat that warms the air supplied for the purpose of ventilation.

(b) To furnish temperature regulation for the temperature in the several rooms of a building.

(c) To so place the heating surface that the heat will be evenly distributed in a room.

*Fourth:*

Air Movement—

(a) To bring the air into the room at such places that a uniform circulation shall obtain in all parts of the room.

(b) To arrange for the placing of desk fans or other appliances in the rooms when the air movement is inadequate.

*Fifth:*

Odor Removal—

To provide for removal of odors when such are objectionable.

## DUST REMOVAL

In considering the dust in the air it is well to recollect that it is found in varying quantities at different times and places. Dr. E. V. Hill[4] found that air taken from the roof of the Chicago City Hall at different times shows a wide variation. The extreme of several samples showed 8,740,000 dust counts per cubic foot. One taken after a night of rain, and while it was still raining, showed 412,000 dust counts per cubic foot. A sample taken from a Chicago street car showed 19,600,000 dust counts per cubic foot.

Almost every one has noticed how clear and delightful the air is after a heavy thunder storm in summer; at such times the air is washed almost clear of dust. The condition of the air as found after a heavy rain storm, the author thinks, might be adopted as a standard for cleanliness till further knowledge determines a better one.

This Society has appointed a committee[5] that is working on the problem of what is a standard for air cleanliness and for a standard method of testing air washers. It is expected within a year it will be able to report some findings of considerable value.

So far as air cleansing is concerned the engineer has an opportunity to improve on the conditions as found in the open, for excepting a few hours after a heavy rain storm, dust is always present in large quantities in the air.

It is not necessary to remove every particle of dust from the air as Nature has provided us with safeguards that prevent a certain amount of dust from reaching the lungs, but the dust in quantities that generally fills the air in our cities, especially in some of our industrial plants, is more or less detrimental to the health of the people who have to breathe it.

From an economical point of view it seems as though it would pay any community to cleanse the air before it enters its buildings as the cost of removing dust from furniture and fabrics and the wear and tear as a result of its presence, is enormous.

## RELATIVE HUMIDITY

That the subject of relative humidity may be understood, the author will outline some of the physical features of aqueous vapor in the atmosphere. This vapor is continuously falling to the earth in the form of dew, rain or snow, which is again evaporated from the oceans, lakes, rivers and to a large extent from the land.

The quantity of vapor in a cubic foot of air varies with the temperature and locality. In Arizona and New Mexico there is much less than in other parts of the United States. The quantity does not depend on the barometric pressure and it seems to be independent of the air it floats in for it can be taken from the air without changing the other constituents.

The elastic pressure of the dry air and the elastic pressure of the vapor added together make what is ordinarily called barometric pressure.

The weight of the moisture and the weight of the dry air added together determine the density of a cubic foot of air and when a cubic foot of air contains as much vapor as it can hold at a given temperature it is saturated (that is, it contains 100%). If any drop in temperature occurs in this volume of air some of the moisture in it will be precipitated. If a rise in temperature occurs the percentage of moisture would become less in proportion.

The following table indicates that there may be as much as twenty grains of moisture in a cubic foot of air. The dry air in this extreme sample at a pressure of 30 pounds in all directions would be 465 grains giving a combined weight of 485 grains.[6]

TABLE 1. PRESSURE AND WEIGHT OF VAPOR AND DRY AIR IN A CUBIC FOOT OF ATMOSPHERE AT A PRESSURE OF 30 LB. WHEN SATURATED, AT VARYING TEMPERATURES.

| Temp. deg. F. | Vapor Pressure | Dry Air Pressure | Vapor weight in gr. per cu. ft. | Dry air weight gr. per cu. ft. | Total weight of saturated air gr. per cu. ft. |
|---|---|---|---|---|---|
| 0 | 0.038 | 29.962 | 0.48 | 605.32 | 605.80 |
| 10 | 0.063 | 29.937 | 0.78 | 591.93 | 592.71 |
| 20 | 0.103 | 29.879 | 1.24 | 578.79 | 580.03 |
| 30 | 0.164 | 29.836 | 1.94 | 565.79 | 567.73 |
| 40 | 0.247 | 29.753 | 2.85 | 552.89 | 555.74 |
| 50 | 0.360 | 29.640 | 4.08 | 539.93 | 544.01 |
| 60 | 0.517 | 29.483 | 5.74 | 526.75 | 532.49 |
| 70 | 0.732 | 29.268 | 7.98 | 513.00 | 520.98 |
| 80 | 1.022 | 28.978 | 10.93 | 598.48 | 509.41 |
| 90 | 1.408 | 28.592 | 14.79 | 482.65 | 597.64 |
| 100 | 1.916 | 28.084 | 19.77 | 465.77 | 485.54 |

The table shows how rapidly the capacity of the air for moisture increases with the rise in temperature. The air will hold 0.78 grains of vapor at 10 deg. fahr. and 7.98 at 70 deg. fahr., rather more than ten times as much. If there was half this quantity of

vapor in the air, say four grains, the relative humidity would be 50 per cent.; that is, half the quantity of moisture the air could hold at that temperature.

It is necessary to inquire into the prevailing relative humidity as it is found to exist in the United States at different places in the open and to contrast these findings with those found in the homes of our people and in the various buildings we inhabit.

It has seemed to the author that if we could ascertain exactly the variations in absolute and relative humidity that exist outside we would be in a better position to determine what is the best absolute or relative humidity to adopt for the air in our buildings.

It is true that we have only recently been able to obtain data as to the relative humidity in the open taken through the different periods of each day, as heretofore the United States Weather Bureau have only given the humidity for the hours of 8 a.m. and 8 p.m. and this was not sufficient information to enable us to determine our needs.

The author has received from the United States Weather Bureau, Washington, D. C., under date of October 25th some tables giving the record of average relative humidity and temperature for the year 1914, taken at the even hours, making twelve readings in twenty-four hours. These readings are arranged to give the average of such hours during the month.

The officials write that as yet no absolutely satisfactory recording instrument has been devised for taking relative humidity, but they say the tables given are from readings made with such instruments and the records were checked by frequent eye observations and they give a fair idea of the mean variations of humidity during the day at the points where the records were made.

*The last three columns in each of the tables and the summary are added by the author.*

The tables show greater differences than one would expect at points fairly close together. Chicago shows an average of the extremes of only 11%, whereas Springfield, Ill., only about two hundred miles distant from Chicago has an average extreme of 21.5%; Burlington, Vt., shows an average of extremes of 19% while those of Fresno, Cal., show 38.5%.

It is unfortunate that we have no records on the Atlantic Coast to compare with those of Fresno on the Pacific. It is also to be regretted that no data of any other large city than Chicago is available, to determine whether humidity is greater in the larger cities than in the country towns or smaller cities, or whether a

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Station. Chicago, Ill — Percentage — Data: Mean Hourly Relative Humidity

| Date 1914 | | A.M. 2 | 4 | 6 | 8 | 10 | Noon | P.M. 2 | 4 | 6 | 8 | 10 | Mid | Extremes of Average Variation | Mean | Mean Average of Vapor Content per C.F. in Grains |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| January | Humidity | 73 | 74 | 74 | 74 | 73 | 72 | 72 | 72 | 72 | 74 | 72 | 72 | 2 | 73 | 1.61 |
| | Temperature | 31 | 31 | 30 | 31 | 32 | 33 | 34 | 35 | 34 | 34 | 34 | 32 | 5 | 33 | |
| February | Humidity | 69 | 69 | 70 | 71 | 67 | 66 | 66 | 65 | 65 | 66 | 67 | 70 | 6 | 68 | 0.89 |
| | Temperature | 19 | 18 | 17 | 18 | 20 | 22 | 24 | 25 | 24 | 23 | 21 | 20 | 8 | 21 | |
| March | Humidity | 70 | 70 | 72 | 70 | 67 | 63 | 61 | 61 | 62 | 66 | 67 | 68 | 11 | 66 | 1.63 |
| | Temperature | 33 | 32 | 32 | 33 | 36 | 38 | 40 | 40 | 39 | 37 | 36 | 35 | 8 | 36 | |
| April | Humidity | 69 | 70 | 71 | 67 | 61 | 58 | 57 | 57 | 63 | 64 | 66 | 67 | 14 | 64 | 2.61 |
| | Temperature | 45 | 45 | 41 | 47 | 49 | 51 | 52 | 52 | 50 | 48 | 47 | 46 | 11 | 50 | |
| May | Humidity | 68 | 70 | 69 | 64 | 58 | 55 | 54 | 54 | 58 | 61 | 64 | 66 | 14 | 62 | 3.83 |
| | Temperature | 58 | 57 | 57 | 61 | 65 | 66 | 67 | 66 | 64 | 62 | 61 | 60 | 10 | 62 | |
| June | Humidity | 72 | 74 | 72 | 68 | 66 | 64 | 62 | 62 | 65 | 69 | 69 | 70 | 10 | 68 | 5.42 |
| | Temperature | 67 | 66 | 66 | 66 | 72 | 73 | 74 | 74 | 72 | 70 | 69 | 68 | 8 | 70 | |
| July | Humidity | 72 | 72 | 72 | 66 | 64 | 61 | 61 | 63 | 67 | 71 | 73 | 74 | 12 | 68 | 6.02 |
| | Temperature | 72 | 71 | 70 | 74 | 77 | 78 | 79 | 78 | 77 | 75 | 74 | 73 | 9 | 73 | |
| August | Humidity | 70 | 70 | 70 | 68 | 61 | 61 | 63 | 62 | 65 | 70 | 69 | 70 | 9 | 67 | 6.03 |
| | Temperature | 71 | 70 | 69 | 72 | 76 | 77 | 78 | 78 | 76 | 74 | 73 | 72 | 8 | 73.5 | |
| September | Humidity | 71 | 73 | 74 | 70 | 62 | 57 | 55 | 55 | 60 | 64 | 68 | 69 | 16 | 65 | 4.74 |
| | Temperature | 64 | 63 | 62 | 64 | 68 | 70 | 71 | 71 | 69 | 68 | 66 | 65 | 9 | 67 | |
| October | Humidity | 77 | 79 | 81 | 78 | 72 | 69 | 64 | 65 | 69 | 73 | 74 | 75 | 17 | 73 | 4.07 |
| | Temperature | 57 | 56 | 55 | 56 | 60 | 62 | 63 | 63 | 62 | 60 | 59 | 58 | 8 | 59 | |
| November | Humidity | 61 | 64 | 67 | 69 | 63 | 58 | 54 | 54 | 56 | 56 | 58 | 60 | 15 | 60 | 2.00 |
| | Temperature | 42 | 41 | 40 | 40 | 43 | 46 | 48 | 48 | 47 | 45 | 44 | 43 | 8 | 44 | |
| December | Humidity | 73 | 74 | 74 | 74 | 71 | 68 | 67 | 67 | 69 | 70 | 71 | 72 | 7 | 71 | 1.07 |
| | Temperature | 24 | 23 | 23 | 23 | 24 | 26 | 27 | 27 | 25 | 25 | 24 | 23 | 4 | 24 | |

Summary

| Winter Months | | Highest Average | Lowest Average | Difference | Mean Average | Average of Extremes Between High and Low | Mean Average for Year |
|---|---|---|---|---|---|---|---|
| October to March | Humidity | 81 | 54 | 27 | 68.5 | 9.66 | |
| | Temperature | 63 | 17 | 46 | 36 | 6 | |
| Summer Months | | | | | | | 11 |
| April to September | Humidity | 74 | 54 | 20 | 66 | 12.5 | 8 |
| | Temperature | 79 | 32 | 47 | 66 | 9 | |

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Station. Springfield Ill — Percentage — Data: Mean Hourly Relative Humidity

| Date 1914 | | A. M. 2 | 4 | 6 | 8 | 10 | Noon | P.M. 2 | 4 | 6 | 8 | 10 | Mid | Extreme of Average Varia | Mean | Mean Average of Vapor Content per C.F. in Grains |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| January | Humidity | 81 | 82 | 83 | 84 | 80 | 74 | 70 | 71 | 74 | 77 | 79 | 80 | 14 | 78 | 1.86 |
| | Temperature | 33 | 32 | 32 | 32 | 34 | 37 | 38 | 39 | 36 | 35 | 35 | 34 | 7 | 35 | |
| February | Humidity | 82 | 82 | 82 | 80 | 74 | 70 | 68 | 70 | 72 | 77 | 78 | 80 | 14 | 76 | 1.04 |
| | Temperature | 19 | 18 | 17 | 17 | 21 | 25 | 27 | 28 | 26 | 24 | 22 | 20 | 11 | 22 | |
| March | Humidity | 82 | 83 | 84 | 82 | 74 | 68 | 65 | 64 | 66 | 72 | 78 | 80 | 20 | 75 | 2.13 |
| | Temperature | 35 | 34 | 34 | 36 | 40 | 42 | 44 | 45 | 43 | 41 | 39 | 38 | 10 | 40 | |
| April | Humidity | 71 | 73 | 74 | 72 | 63 | 58 | 54 | 53 | 55 | 59 | 65 | 68 | 20 | 64 | 3.03 |
| | Temperature | 49 | 48 | 47 | 51 | 56 | 59 | 61 | 61 | 59 | 56 | 53 | 51 | 13 | 54 | |
| May | Humidity | 67 | 69 | 70 | 61 | 52 | 46 | 44 | 43 | 46 | 53 | 58 | 63 | 27 | 56 | 4.21 |
| | Temperature | 60 | 58 | 57 | 66 | 72 | 75 | 76 | 77 | 74 | 69 | 66 | 63 | 20 | 68 | |
| June | Humidity | 68 | 71 | 72 | 62 | 53 | 48 | 45 | 44 | 45 | 51 | 58 | 64 | 28 | 57 | 5.89 |
| | Temperature | 71 | 69 | 64 | 76 | 82 | 85 | 87 | 87 | 84 | 80 | 76 | 73 | 18 | 78 | |
| July | Humidity | 66 | 69 | 70 | 58 | 48 | 40 | 36 | 37 | 41 | 50 | 56 | 60 | 34 | 53 | 5.99 |
| | Temperature | 73 | 71 | 70 | 78 | 84 | 89 | 92 | 91 | 87 | 82 | 78 | 76 | 22 | 81 | |
| August | Humidity | 71 | 73 | 76 | 70 | 60 | 53 | 49 | 50 | 53 | 63 | 67 | 70 | 27 | 63 | 5.58 |
| | Temperature | 71 | 69 | 67 | 73 | 79 | 83 | 85 | 85 | 83 | 78 | 75 | 73 | 18 | 77 | |
| September | Humidity | 79 | 81 | 82 | 77 | 68 | 61 | 58 | 57 | 59 | 67 | 72 | 76 | 25 | 70 | 5.89 |
| | Temperature | 62 | 60 | 59 | 64 | 71 | 74 | 76 | 76 | 73 | 68 | 66 | 64 | 17 | 68 | |
| October | Humidity | 81 | 83 | 85 | 83 | 73 | 65 | 61 | 61 | 65 | 72 | 77 | 80 | 24 | 74 | 4.00 |
| | Temperature | 53 | 52 | 51 | 54 | 61 | 64 | 66 | 66 | 62 | 58 | 56 | 54 | 15 | 58 | |
| November | Humidity | 67 | 69 | 71 | 71 | 65 | 53 | 49 | 48 | 54 | 59 | 62 | 65 | 19 | 61 | 2.11 |
| | Temperature | 42 | 41 | 39 | 40 | 46 | 51 | 54 | 54 | 49 | 46 | 44 | 43 | 15 | 46 | |
| December | Humidity | 86 | 87 | 87 | 87 | 86 | 84 | 82 | 81 | 81 | 82 | 83 | 84 | 6 | 84 | 1.33 |
| | Temperature | 24 | 23 | 22 | 22 | 24 | 26 | 28 | 27 | 26 | 25 | 24 | 24 | 6 | 25 | |

Summary

| Winter Months | | Highest Average | Lowest Average | Difference | Mean Average | Average of Extremes Between High and Low | Mean Average for Year |
|---|---|---|---|---|---|---|---|
| October to March | Humidity | 87 | 54 | 33 | 74.66 | 16.16 | |
| | Temperature | 66 | 17 | 49 | 38 | 11 | |
| Summer Months | | | | | | | 21.5 |
| April to September | Humidity | 82 | 40 | 42 | 60.5 | 26.83 | 14 |
| | Temperature | 92 | 47 | 45 | 71 | 18 | |

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Station. Burlington, Vt. — A.M. — Percentage — P.M. — Data. Mean Hourly Relative Humidity

| Date 1914 | | 2 | 4 | 6 | 8 | 10 | Noon | 2 | 4 | 6 | 8 | 10 | Mid | Extreme of Average Varia | Mean | Mean Average of Vapor Content per C.F. in Grains |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| January | Humidity | 80 | 79 | 80 | 79 | 76 | 74 | 71 | 72 | 74 | 76 | 78 | 80 | 9 | 76 | 0.79 |
| | Temperature | 14 | 14 | 13 | 13 | 15 | 17 | 19 | 18 | 17 | 16 | 16 | 15 | 6 | 15.7 | |
| February | Humidity | 71 | 73 | 73 | 73 | 68 | 64 | 62 | 62 | 63 | 67 | 70 | 69 | 8 | 68 | 0.54 |
| | Temperature | 8 | 7 | 7 | 7 | 11 | 14 | 15 | 15 | 12 | 11 | 10 | 9 | 8 | 10.5 | |
| March | Humidity | 76 | 77 | 77 | 76 | 69 | 66 | 63 | 66 | 70 | 71 | 74 | 75 | 7 | 71 | 1.32 |
| | Temperature | 26 | 26 | 26 | 26 | 30 | 32 | 33 | 32 | 30 | 29 | 28 | 27 | 7 | 28.9 | |
| April | Humidity | 74 | 75 | 76 | 72 | 65 | 62 | 59 | 60 | 61 | 66 | 70 | 74 | 16 | 68 | 1.81 |
| | Temperature | 34 | 33 | 33 | 36 | 40 | 42 | 43 | 44 | 41 | 38 | 37 | 35 | 10 | 38 | |
| May | Humidity | 69 | 74 | 72 | 64 | 56 | 49 | 45 | 44 | 47 | 51 | 63 | 70 | 25 | 60 | 3.24 |
| | Temperature | 51 | 50 | 49 | 55 | 59 | 64 | 66 | 66 | 64 | 61 | 57 | 53 | 16 | 58 | |
| June | Humidity | 76 | 77 | 73 | 66 | 57 | 51 | 48 | 52 | 54 | 60 | 66 | 74 | 28 | 57 | 3.77 |
| | Temperature | 56 | 54 | 56 | 60 | 64 | 68 | 69 | 70 | 68 | 64 | 61 | 58 | 16 | 64 | |
| July | Humidity | 86 | 88 | 85 | 77 | 68 | 61 | 58 | 58 | 64 | 73 | 82 | 84 | 24 | 74 | 5.40 |
| | Temperature | 60 | 59 | 60 | 65 | 69 | 72 | 74 | 74 | 72 | 68 | 64 | 62 | 12 | 66.7 | |
| August | Humidity | 90 | 90 | 87 | 81 | 67 | 62 | 59 | 58 | 68 | 76 | 82 | 86 | 32 | 67 | 4.14 |
| | Temperature | 62 | 59 | 59 | 64 | 69 | 70 | 72 | 74 | 71 | 66 | 64 | 62 | 15 | 62 | |
| September | Humidity | 85 | 85 | 85 | 80 | 64 | 55 | 52 | 54 | 60 | 70 | 80 | 82 | 33 | 71 | 38.3 |
| | Temperature | 52 | 51 | 50 | 55 | 61 | 65 | 66 | 66 | 62 | 58 | 55 | 53 | 16 | 58 | |
| October | Humidity | 78 | 80 | 83 | 80 | 70 | 62 | 58 | 60 | 64 | 70 | 72 | 75 | 25 | 71 | 3.13 |
| | Temperature | 47 | 46 | 45 | 47 | 52 | 55 | 57 | 57 | 53 | 51 | 49 | 48 | 12 | 51.7 | |
| November | Humidity | 72 | 73 | 75 | 75 | 68 | 64 | 61 | 65 | 67 | 67 | 68 | 70 | 14 | 74 | 1.70 |
| | Temperature | 32 | 32 | 32 | 32 | 35 | 37 | 38 | 36 | 34 | 34 | 34 | 33 | 5 | 34 | |
| December | Humidity | 73 | 73 | 75 | 75 | 71 | 66 | 66 | 67 | 70 | 70 | 71 | 72 | 9 | 70 | 0.91 |
| | Temperature | 20 | 19 | 18 | 18 | 22 | 24 | 26 | 25 | 22 | 22 | 20 | 20 | 8 | 21.4 | |

Summary

| Winter Months | | Highest Average | Lowest Average | Difference | Mean Average | Average of Extremes Between High and Low | Mean Average for Year |
|---|---|---|---|---|---|---|---|
| October to March | Humidity | 83 | 58 | 25 | 71.66 | 12 | 19 |
| | Temperature | 57 | 7 | 50 | 42 | 8 | 11 |
| Summer Months | | | | | | | |
| April to September | Humidity | 90 | 44 | 46 | 65.66 | 26.33 | |
| | Temperature | 74 | 26 | 48 | 27 | 14 | |

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Station Fresno, Cal. — A.M. — Percentage — P.M. — Data. Mean Hourly Relative Humidity

| Date 1914 | | A.M. 2 | 4 | 6 | 8 | 10 | Noon | P.M. 2 | 4 | 6 | 8 | 10 | Mid | Extreme of Average Varia. | Mean Average | Mean Average of Vapor Content per C.F. in Grains |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| January | Humidity | 90 | 89 | 88 | 86 | 81 | 75 | 69 | 70 | 80 | 84 | 88 | 89 | 21 | 76 | 3.10 |
| | Temperature | 47 | 46 | 46 | 46 | 50 | 53 | 55 | 55 | 52 | 50 | 49 | 48 | 9 | 50 | |
| February | Humidity | 90 | 91 | 92 | 92 | 83 | 66 | 60 | 61 | 70 | 82 | 87 | 91 | 32 | 80 | 3.52 |
| | Temperature | 47 | 47 | 44 | 44 | 51 | 57 | 60 | 60 | 57 | 54 | 52 | 45 | 16 | 51.5 | |
| March | Humidity | 88 | 88 | 90 | 85 | 68 | 57 | 50 | 48 | 57 | 72 | 78 | 86 | 42 | 72 | 4.01 |
| | Temperature | 52 | 50 | 48 | 50 | 59 | 65 | 68 | 70 | 67 | 62 | 58 | 54 | 22 | 58.5 | |
| April | Humidity | 80 | 80 | 82 | 72 | 59 | 47 | 42 | 41 | 46 | 59 | 69 | 76 | 41 | 71 | 4.38 |
| | Temperature | 53 | 52 | 50 | 55 | 62 | 67 | 70 | 71 | 68 | 63 | 59 | 56 | 21 | 61.3 | |
| May | Humidity | 68 | 73 | 75 | 60 | 46 | 37 | 31 | 28 | 28 | 38 | 51 | 61 | 47 | 50 | 3.87 |
| | Temperature | 59 | 56 | 56 | 63 | 71 | 76 | 80 | 82 | 80 | 73 | 67 | 62 | 24 | 69 | |
| June | Humidity | 55 | 61 | 63 | 51 | 40 | 31 | 24 | 21 | 22 | 29 | 40 | 47 | 42 | 41 | 3.75 |
| | Temperature | 63 | 60 | 60 | 69 | 76 | 82 | 86 | 87 | 85 | 78 | 71 | 67 | 27 | 73.6 | |
| July | Humidity | 49 | 54 | 56 | 47 | 36 | 27 | 20 | 17 | 17 | 24 | 33 | 42 | 33 | 35 | 3.96 |
| | Temperature | 69 | 66 | 65 | 73 | 82 | 89 | 94 | 97 | 95 | 87 | 79 | 74 | 32 | 81 | |
| August | Humidity | 49 | 53 | 57 | 49 | 38 | 28 | 21 | 17 | 17 | 24 | 33 | 44 | 54 | 36 | 3.93 |
| | Temperature | 69 | 66 | 64 | 72 | 78 | 89 | 94 | 97 | 94 | 85 | 78 | 72 | 33 | 80 | |
| September | Humidity | 56 | 61 | 66 | 58 | 44 | 34 | 29 | 26 | 28 | 34 | 43 | 51 | 46 | 44 | 3.51 |
| | Temperature | 61 | 59 | 57 | 64 | 73 | 80 | 84 | 86 | 82 | 75 | 69 | 65 | 29 | 69.6 | |
| October | Humidity | 67 | 70 | 74 | 66 | 50 | 41 | 36 | 35 | 40 | 47 | 56 | 63 | 39 | 54 | 3.58 |
| | Temperature | 56 | 54 | 52 | 57 | 66 | 72 | 76 | 76 | 72 | 66 | 62 | 59 | 24 | 64 | |
| November | Humidity | 66 | 70 | 73 | 69 | 52 | 39 | 34 | 33 | 39 | 47 | 53 | 60 | 40 | 54 | 2.83 |
| | Temperature | 49 | 46 | 44 | 47 | 58 | 66 | 70 | 70 | 65 | 60 | 55 | 51 | 26 | 56.7 | |
| December | Humidity | 86 | 89 | 89 | 90 | 84 | 76 | 69 | 66 | 76 | 83 | 86 | 89 | 24 | 61 | 2.04 |
| | Temperature | 42 | 40 | 39 | 40 | 44 | 48 | 51 | 50 | 48 | 46 | 44 | 42 | 11 | 44.5 | |

Summary

| Winter Months | | Highest Average | Lowest Average | Difference | Mean Average | Between High and Low Average of Extremes | Mean Average for Year |
|---|---|---|---|---|---|---|---|
| October to March | Humidity | 92 | 33 | 59 | 66.16 | 33 | 37 |
| | Temperature | 76 | 40 | 36 | 54 | 18 | 23 |
| Summer Months | | | | | | | |
| April to September | Humidity | 82 | 17 | 65 | 44 | 40.5 | |
| | Temperature | 97 | 50 | 47 | 72 | 28 | |

city located on the shore of a lake would have a higher relative humidity than one inland.

Take the extreme variation in the Chicago table and it will be seen that the highest mean relative humidity for the winter months is 81% and the lowest 54%, and the average of the extreme variations, 9.66%. A study of this table will show that the high and low periods were very close together, the high being in October and the low in November, an extreme average variation of only 27%.

Now note the Burlington, Vt., table. The highest mean relative humidity for the winter months is 83% in October and the lowest, 58%, also in October. In this table these high and low periods are in the same month and show an extreme variation of 25%, but the average of the difference is only 12%.

Next take the table for Springfield, Ill.; the highest relative humidity for the winter months is 87%, which is in October and the lowest 54% in November, and the average of the extreme differences is 16.16%.

Then consider the table for Fresno, Cal., and see how much wider the extremes are apart; 92% in February and 33% in November with a difference of 59% and the averages of the extreme difference is 60.5%.

It would seem from these tables that we should have no trouble in ascertaining what is the best relative humidity, but the figures show that we are accustomed to considerable fluctuations, if we are to be guided by outside conditions. It is interesting to note that the lowest average humidity, except at Fresno, is 54%.

It is now in order to consider the condition of relative humidity as found in our homes and buildings. It is probably in respect to humidity that we have gone to extremes in producing artificial conditions, and greatly to the detriment of our physical welfare.

It is difficult to give a definite record of the relative humidity found in our homes and offices, as but few people know what the conditions are. Enough, however, has been learned to be sure that it runs very low in our homes and still lower in offices and stores. It can be stated in a general way that the relative humidity in stores and offices will be as low as 20%, and frequently it will run as low as 10%. Mr. F. L. Busey[7] speaks of humidity as low as 8%. Mr. J. I. Lyle[8] speaks of humidity in office buildings from 8% to 20%. Mr. Whitten and Mr. Davis[9] speak of relative humidity as low as 10% to 20% in a school. Dr.

Thomas Hubbard[10] tells of cases from 14% to 20% in furnace heated schools.

The author took readings in the office of the Society during January and March, 1915, and the extreme range was from 21% to 57% for January with an average of 42% and for March the extreme range was from 30% to 40%, with an average of 37%.

A member of the Society also made some readings at his office and home as follows:

The office is on the tenth floor of a building with a floor above and below heated in a similar manner by direct radiation. The relative humidity range for eighteen days in February, 1915, was 23% to 39%, with an average of 25%.

In his home, which is located at Newark, N. J., the readings were made from a room that opens into the general living room with sliding doors which were always open; the extreme range of eighteen readings was 28% to 46%, with an average of 37%.

It may be well to consider in connection with this paper the results that have been attained in the New York Stock Exchange which is supplied with cooling apparatus to reduce the temperature of its rooms when the heat or humidity outside becomes excessive.

This association has, usually from twelve to fifteen hundred men and boys on the exchange floor during business hours and they are nervous and excitable people. The room conditions as to temperature and humidity that have been found suitable for the average of this number and class of people may be assumed to be as nearly correct as it is possible to attain.

They have found it necessary at times to cool the air in this building in December and March, when the temperature reached 70 degrees or over with high relative humidity.

The air for cooling this building is reduced in temperature to a range of 57 deg. to 62 deg. or an average of 60 deg. (see diagram, Fig. 1[15]) and at that temperature it is delivered into the room through the registers located 80 feet above the floor line. The air delivered to the room contains approximately 100% of moisture, but in mixing with the air of the room the temperature is raised to 74 deg. when the quantity of moisture becomes about 60%, varying with the amount contained in the air of the room.

The temperature that is maintained in the summer is not uniformly at 70 deg., but is made relative to the outside temperature as determined by actual experience in providing for the comfort of the large number of people who use this exchange.

The diagram, Fig. 1, [15] shows how the inside temperatures vary with the outside differences.

For instance, with the outside temperature of 90 deg. the inside temperature is maintained at slightly less than 79 deg., whereas with an outside temperature of 80 deg. the inside temperature is slightly less than 74 deg., these temperatures being the ones that gave the best results, determined by constantly watching the effect of different conditions on the occupants of the room.

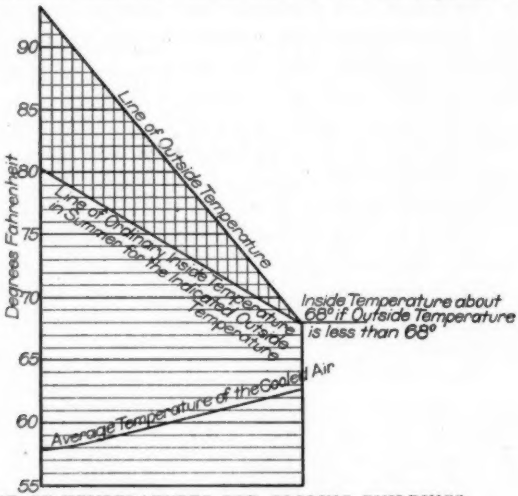


FIG. 1. RANGE OF TEMPERATURES FOR COOLING BUILDINGS.

Their experience in operating this plant demonstrates that an inside temperature of 70 deg. when the outside temperature reaches above 75 deg. or 76 deg. fahr., is neither healthy nor desirable.

TEMPERATURE CONTROL

As the engineer has to provide a plant of sufficient capacity to heat a building in the coldest weather it follows that for the greater part of a heating season the apparatus is much too large for the requirements and the danger of overheating a building is always present.

It is therefore of the first importance that adequate means should be provided to regulate the heating apparatus that excessive temperature may be avoided.

Recent researches have indicated that one of the most baneful factors involved in ventilation is too much heat.[11]

This additional heat, that is very detrimental to health, also

costs much money, hence the use of automatic regulating apparatus is almost always a direct saving in operating cost.

Dr. Hubbard says:[12] "It costs as much to raise the temperature in cold weather from 60 deg. to 70 deg. as it does to raise the temperature from 20 deg. to 60 deg. F.," and while this statement may be questioned, there is no doubt that there is a greater proportionate loss involved in heating a building up to 70 deg. than would be the cost in heating up to only 60 deg.

There are many reasons to indicate that we warm our buildings to too high a temperature and that one of the necessities of good ventilation is to provide means to keep the heat from rising beyond the point where it is best for the proper development of our people.

This temperature, it would seem, should be adjusted to the purposes the building or rooms are to be used for. A bedroom does not need as high a temperature as a dining- or living-room, but excessive temperatures should be avoided.

### TEMPERATURE

In dealing with the temperature of the outside air we have to consider the effect the sun has on the atmosphere and how hot the air becomes from the radiation that comes from the sun to the earth and from the earth to the air.

It will be remembered that it is but rarely that the temperature reaches above 100 deg. If we are to accept natural conditions as a standard we are using means for heating the air very much in excess of that supplied by nature.

Steam coils as used for heating the air for ventilating are at an average temperature of about 210 deg. It is possible that this temperature is too high and that some means should be devised as by using hot water in place of steam that a temperature down to 120 deg. or less may be employed.

It is also possible, however, that if the air is washed clear of particles that might be changed by coming into contact with surfaces heated to a temperature equal to atmospheric steam, this temperature might not be injurious to it, but the author is of the opinion that it is safer to use surfaces at a low temperature as being more in accord with natural conditions.

In northern climates the variations of temperature extend through the year over a range of 100 or more degrees, as in the summer it is often as high as 85 or more degrees and just as often in winter in some localities it is as low as 15 or more degrees below zero Fahr.

At the extreme of either of these temperatures man does not flourish mentally or physically and is not comfortable; hence we can assume that man in cold weather must have some means of retaining his body heat or he cannot continue to exist, and likewise in the time of extreme heat in summer he must have some means of disposing of the extra temperature or he must change his food and reduce his activity to avoid generating excessive heat.

### AIR MOVEMENT

The question of air movement in our buildings has never received the attention the subject deserves and the author is strongly of the opinion that this particular function will do more to provide adequate ventilation than any of the requirements heretofore mentioned.

In the open air there is almost always more or less air movement and such a condition as "dead air space" would be hard to find. Contrast this with the conditions in our buildings in which the air is almost always stagnant and "dead air spaces" can be found in almost any room, and very often in those rooms that are provided with as much air as thirty cubic feet per capita.

Dr. Thos. R. Crowder[13] says that in the open air standing free with a light breeze blowing the reinspiration of expired air could not be detected, but in almost all his experiments indoors a definite amount of expired air was reinhaled, except when a draft from a fan was blown towards the face.

It is true that Dr. Crowder says a reinspiration of a portion of the expired air is not injurious, and the author only uses this reference to illustrate the fact that a condition of still air almost never exists in the open and that Dr. Crowder's experiments show conclusively that only constant air movement will carry off the emanations from the body whether those be $CO_2$, heat or odors.

The Chicago Commission on Ventilation[14] in their experiments in school rooms show how hard it is to get uniform air movement in the rooms and that their experiments are largely directed towards the procuring of better diffusion of the air for the use of the pupils.

The author is quite convinced, after a careful study of the subject, that a thorough diffusion and a constant movement of the air in the rooms of our buildings is the most important factor in the production of good ventilation and that if the location of the fresh air inlets by which fresh air is delivered to rooms is such that the

current does not reach every part of the room, such rooms *should be provided with desk fans, or fans of some other type so placed that they will insure the absolute diffusion and continuous movement of the fresh air to all parts of the room.*

## CONCLUSION

The author presents this paper for the purpose of showing that it may be possible to arrive at a standard for the factors in ventilation by contrasting the condition of the air in our buildings with that of the air outside and that if data could be collected from a number of buildings showing the relative humidity and the lack of air movement, we could soon know how greatly the conditions in our buildings differed from those in the open air.

One thing seems to be apparent in the foregoing inquiry, and that is the constant changing of all the factors that enter into the problem of ventilation, and it may be that one of the reasons for the healthfulness of the outer air is the constant changing in the air movement, humidity, temperature, sunlight, etc., that continually take place in the aerial envelope or atmosphere that surrounds the earth, which is our natural environment.

The United States Government Weather Bureau have established stations for taking relative humidity at the following cities: Sacramento, San Francisco, Fresno, Los Angeles and San Diego, Cal; Boise, Idaho; Sheridan, Wyoming; Lincoln, Nebraska; Chicago and Springfield, Ill.; St. Louis, Mo.; Meridian, Miss.; Grand Rapids, Mich.; Columbus, Ohio; Ithaca, N. Y.; Washington, D. C.; Tampa, Fla., and Burlington, Vt. However, it will be a year or two before they will have gathered enough data to enable them to present the actual relative humidity at all of those stations.

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[1] Encyclopedia Britannica, XI Edition.

[2] Dr. T. R. Crowder (Ventilation of Sleeping Cars. Transactions of the Society, 1915, Vol. XXI).

[3] Paper by Arthur K. Ohmes in bulletin, Institute of Operating Engineers, April and May, 1913.

[4] Inspection of Theaters and Ventilation Division, Chicago Health Department. Transactions of the Society, Vols. XIX and XX.

[5] Committee to determine a standard method of testing air washers, Transactions of the Society, 1914, Vol. XX.

[6] U. S. Weather Reports, 1900.

[7] Transactions of Society, Busey & Carrier, 1913, Vol. XIX.

[8] Relative Humidity, Transactions of the Society, 1912, Vol. XVIII.

[9] Transactions of Society, 1913, Vol. XIX, pages 123 and 124.

[10] Dr. Thos. Hubbard, President's Address, American Laryngological Association, May, 1914.

[11] M. W. Franklin, Transactions of the Society, 1915, Vol. XX.

[12] Same as reference 9.

[13] Reinspiration of Expired Air, American Medical Association, Transactions, 1913.

[14] Transactions of the Society, Vol. XXI, 1915.

[15] Heizungs, Lueftungs, und Dampfkraft Anlagen in den Vereinigten Staaten von Amerika.—Heating, Ventilating and Steam Power Plants in the United States of America, Arthur K. Ohmes.

## DISCUSSION

DR. E. V. HILL: The question is not "Can we standardize ventilation requirements?" but rather "Why have we not standardized long before this?" A good many think that it is wrong to adopt standards for the reason that we appear to be tying ourselves to something that is unalterable and unchanging. If I am asked whether or not we have sufficient data at hand to establish such fixed and unalterable standards I should have to say no. It is essential that we do adopt such standards, as I feel strongly it is the only avenue of progress. It may be necessary to change them next month or next year, but even so it is far better to do this than to drift along with no standards at all.

In steam heating work the standards that have been established are comparatively simple. When an engineer draws specifications he designs an equipment that will maintain a temperature of 70 deg. when the outside temperature is zero and he expects that that standard will be fulfilled when the installation is completed and tested. In designing a ventilating equipment the contractor is simply instructed to furnish apparatus that will supply so many cubic feet of air, with possibly some restrictions regarding velocity and pressure. Practically all of the other essential factors that enter into the problem of ventilation are neglected.

The result of this is that the heating and ventilating engineer is falling, or I might say has fallen into disrepute, to an extent at least, because the operation of the equipment which he designed does not come up to expectations of the purchaser. This is due almost entirely to the fact that there are no standards regarding many of the important features in ventilation practice which should be specified in the contract and fulfilled by the operation of the equipment.

This can perhaps, be best illustrated by a recent experience I had in a school in one of the suburbs of Chicago. The School Board wrote asking us to make a test of the air conditions. This we did, determining the air supply, distribution, bacterial content, dust content, etc., and wrote to them giving the results of our tests and observations. They immediately wrote back saying that while our tests were probably very complete they meant nothing at all to them and asked if we could not supply them with some standards for school ventilation with which the tests could be compared. I, therefore, revised the report, giving

the standards which I consider desirable in certain columns together with the results of tests of these conditions. The standards used were as follows:

| | |
|---|---|
| Air supply per pupil | 30 cu. ft. per min. |
| $CO_2$ content | 8 parts in 10,000 parts of air. |
| Temperature | 68 deg. Fahr. |
| Relative humidity | 42 per cent. |
| Dust count | 100,000 particles per c.c. |
| Bacteria | 12 colonies on a three-minute plate. |
| Air movement | 2 ft. per second. |

With the exception of the humidity and the air supply of 30 cu. ft. per min. the standards suggested should be considered as maximum.

Tests in the school room referred to show something over the 30 cu. ft. per min. suggested as a standard. The colony count, dust count, etc., were in general less than the maximum allowed by these standards. In two rooms where no mechanical equipment had been provided the amount of air fell considerably below the standards mentioned; the $CO_2$ and the bacteria counts much above. It is already apparent that an air movement in a room of 2 ft. per second is objectionable in some cases and this will have to be reduced. It is probable also that other standards will have to be added and some of these changed, but I am sure that it is better to use these as a basis for comparison than to have none at all.

For testing air movements in a room we use a small apparatus consisting of two 125 c.c. rubber stoppered bottles, one containing hydrochloric acid and the other ammonium hydroxate. By means of a small hand pump air is forced through the two bottles simultaneously and the volatilized substances mingled at the outlet nozzle. A chemical reaction occurs between the acid and the alkali, forming ammonium chloride, which floats through the air as a dense white cloud. Stationing a second observer in the direction of the air movement, 10 ft. from the apparatus, it is an easy matter to determine the velocity of the air movement by timing the travel of the puff of smoke from this device.

In testing for bacteria we expose a culture plate for three minutes, incubate for 48 hours at room temperature, and count the colonies. In a properly ventilated room the count will be below 12. Methods of taking air samples, making dust counts, etc., you are familiar with and I will not repeat them here.

These are the standards which we are using, I think with good results, in Chicago and I feel strongly that this is the way to make progress in determining why unsatisfactory results are so often encountered in mechanically ventilated buildings. I believe we can help forward the work of this organization by using standards of this kind in testing.

Answering the question as to our method of calculating dust counts, the most consistent results are obtained by the use of the filtration method. We use, however, the Aitken dust counter as it is much easier to operate and requires much less time. The difficulty with the Aitken method is that it shows every minute, or I should say microscopic dust particle which escapes observation with the filtration method. We get, therefore, a much higher count with the Aitken machine than with the filtration method. In regard to making bacterial observations, I will say that we have tried various methods—the Caldwell tube, sand filter, etc.,—but for practical work, we have discarded these and rely on an ordinary Agar plate exposed usually for three minutes and incubated for forty-eight hours at room temperature. Colony counts are made at the end of the incubation period and noted on our record card. We have exposed something like 3,000 plates in the last two and one-half years in school class rooms, theatres, street cars, etc., and checked the number of bacteria against other air conditions in these places. In this way we have arrived at 12 as a maximum number of colonies in properly ventilated rooms. Where efficient air washers are in operation, it is unusual to get a colony count above this number.

H. M. HART: I was surprised to note the results obtained in the Stock Exchange, where the conditions are given as 74 deg. with 60 per cent. humidity. Probably this is due to the fact that it was a summer day. The outdoor conditions do not always mean the most comfort, as noted when checking up the chart, showing the comfort zone, given by the Chicago Commission on Ventilation. The conditions given in this are about those of a fine spring day, but the relative humidity and the temperature can vary quite a good deal, from natural conditions. These observations covered a period of two years, and tests and observations show that outside conditions are not always of the most comfort.

We are interested in establishing standards, and I believe the standards which Dr. Hill shows have been accepted as a

basis from which to work. I agree that we need not consider the standard as the last word, and so be afraid to accept it for fear we could not change it.

Prof. Wm. Kent: The author states as his opinion that it is safer to use surfaces of low temperature for heating, as they are the more natural ones and follow natural conditions. He refers to 120 deg. as a usual temperature obtained in hot water heating. We have used temperatures from 120 to 2,000 deg. for obtaining heat, from live steam and from gas-logs, stoves, fire-places and electric heaters and I know of no evidence that there is any disadvantage from the use of these high-temperature mediums.

The question in the paper is, "Can we standardize ventilation requirements," and I think the answer is "Yes" and "we have." The heating and ventilating engineer and the medical profession have for many years had the standard of 30 cu. ft. of air per minute per occupant for ventilating purposes, and recent investigations have shown that while this quantity is not necessary for removing the $CO_2$, it is necessary for removing the body heat and keeping the occupants comfortable.

It is well established in New York that with a temperature between 66 and 72 we can be rendered very comfortable if the humidity is not too high. There is a difference of opinion in regard to humidity. The Chicago Commission shows what they consider the comfort zone, while Prof. Winslow gives other figures, showing 20 per cent. as the desirable relative humidity at 75 deg., and 90 per cent. at 55 deg.

With high temperature, we want a dry atmosphere. We suffer when we have a temperature of 60 deg. to 70 deg., and a high humidity. At this temperature, about 30 per cent. humidity is satisfactory.

We thus have fairly good standards as far as volume, temperature and humidity are concerned. We have as yet no standards for dust and for bacteria, but they can be obtained, no doubt, after a few years of systematic research.

Dr. E. V. Hill: Professor Allen made an inquiry regarding the Comfort Zone Chart. I will say that there were 152 observations made in the experimental room of the Chicago Normal College under varying conditions of temperature and humidity. The pupils were at work at their regular duties when the tests were conducted. They would be asked how they felt regarding temperature, etc., and their answers recorded. The results were plotted on the chart and the curve made up from this data.

The zone through the center, indicating the conditions that are comfortable, you will note, is quite wide, the line through the center of this zone indicating the average humidity and temperature for this region. It is apparent that the humidity can vary within quite a wide range and still fall within the zone of comfort.

Regarding the question asked as to housing standards, I will say that I do not feel competent to answer it. These standards have been worked out on the basis of floor area per occupant. The Chicago Code requires that the cubic contents for a habitable room shall not be less than 400 cu. ft. per occupant.

THE AUTHOR: The reason why I investigated the plant of the Stock Exchange was because means were provided for cooling the air in summer and I wanted to see if I could arrive at a conclusion from the results obtained from this plant as to whether an inside temperature of 70 deg. with an outside temperature of from 65 deg. down to zero, was always desirable.

In using this plant, they have had considerable experience in providing various degrees of humidity and temperature. I had several interviews with the chief engineer in charge and he told me they could not maintain 70 deg. in the building with safety, when the temperature outside was above 76 deg., for the building was too cool and consequently they had to raise the temperature. In other words, there was a relation between inside and outside conditions which they found it wise to consider. If it was 90 deg. outside, the occupants of the building were most comfortable when the temperature was kept at 75 deg.

They have some interesting records covering long periods of time from which they found that it was to their advantage to maintain other temperatures than 70 deg. with the outside conditions varying from 60 deg. down to zero.

Mr. Kent has stated that high temperature surfaces for heating buildings are not objectionable; that there is difficulty in getting evidence that high temperatures are injurious. I have heard many strong objections to fire-places and gas-logs. In my own house I have two gas-logs, and whenever ony one lights them there is always a strong objection raised on account of objectionable odors.

I want to call attention to the fact that outside of our buildings there is continual change in air movement and in like manner, the humidity is always changing. It is just possible that we should not adhere closely to 70 deg. for the inside temperature and 60 per cent. humidity without regard to other conditions. My

idea is that it is best to see if we can determine if a study of outside conditions will be of any aid to us in our efforts for improving the healthfulness of the air in our buildings. The question of relative humidity, unless taken in connection with temperature, will be ineffective.

It will be a good idea for our members to undertake to collect records of relative humidity and temperature in the various sections of the country, so that we might find out how variable it may be in the different states.

## No. 413

# PROCEEDINGS

## OF THE

## SEMI-ANNUAL MEETING — 1916

JULY 19-21, 1916

THE Semi-Annual Meeting of THE AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, for 1916, which was the fortieth regular meeting of the Society, was the largest attended and one of the most successful summer meetings in its history. The meeting was held at Detroit, Mich., on July 19, 20 and 21, with headquarters at the Hotel Statler. The arrangements for the meeting were made by the recently formed Michigan Chapter, whose liberal efforts in providing for the entertainment of the visiting members contributed largely to the success of the meeting. The registration at the meeting was 92 members and 66 guests. The meeting was conducted under the chairmanship of H. M. Hart, President of the Society.

### FIRST SESSION—WEDNESDAY A. M., JULY 19, 1916

The meeting was called to order at 11 A. M. by President Hart, who announced that the Mayor of Detroit had found it impossible to be present to formally welcome the members of the Society and that he had sent Mr. James H. Lee, of the Corporation Counsel's office as his representative. Mr. Lee spoke in part as follows:

JAMES H. LEE: It is customary when Detroit entertains a convention, for the Mayor on behalf of the city to extend a welcome to the visiting delegates. Detroit is perhaps the greatest convention city in the United States and the Mayor is kept busy seeking to extend the official hand of welcome to those who are within our gates. You can readily appreciate that because of the numerous conventions that meet here, it is utterly impossible for his honor to attend them all. So it is my humble

duty this morning, in the best way I can in behalf of him, and in the name of this great city of Detroit, to extend to you gentlemen a welcome.

I want to say that we extend to you visitors a most hearty and sincere welcome. Those of you who have never been with us before will be astounded at the marvelous progress made by the city of Detroit in the last fifteen years. We want you to see not only something of our industrial progress, but something of our municipal progress, and our improvement along the lines of municipal welfare. I think you have already had admiration, if you have not expressed it, for our excellent system of traffic regulation. Detroit is, perhaps, as you doubtless know, the most congested automobile city in the United States, being the home of the automobile, and I am sure that we have solved the problem, the municipal problem, which is one of many, of an adequate and efficient traffic regulation.

To digress I want to say that the Society of which you are representatives has, of my own personal knowledge, within its membership one man who must be very capable and very efficient, because the Mayor of the City of Detroit has seen fit to appoint him to the Building Commission of this city—a very important Commission. Mr. W. F. McDonald, who, I understand, is a moving spirit in the local Chapter of this organization, has brought to the Building Commission of Detroit, which it has been one of my pleasant duties to advise, his expert knowledge of ventilating and heating, filling a long-felt want, and he has been engaged, of my own knowledge, in an earnest and sincere effort to so revise and so amend the Building Code of this city as to standardize it and make it scientific and efficient, not only so far as the heating and ventilation of our public buildings are concerned, but in all other respects. If we had more men on the honorable boards of the city of Detroit—men who serve without any remuneration whatsoever, men who oftentimes the average citizen does not know to be giving their time, men that are capable of earning big incomes, men like Mr. McDonald, who is an efficient and capable man, giving hours of his time free to the City of Detroit—I want to say, that if we had more men like that, the city would have a better government.

I desire to express to you the sincere regrets of his honor, Mayor Marx, for his inability to be here. He is out at Mt. Clemens this morning. But to you, gentlemen, we extend a sincere welcome. We know that you delegates, ladies and the others who have come with you, will appreciate

Detroit and we know you will go away from our fair city saying that you made no mistake when you brought your convention to the city wherein is located the youngest, and, as I understand, one of the most progressive and rapidly growing Chapters of your organization.

PRESIDENT HART: In behalf of THE AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, I wish to thank our kind Detroiters through their Mayor for this hearty welcome. I am sure that all of those who are not fortunate enough to live in Detroit are very glad of this opportunity to visit this wonderful city, which has been so persistent, and successful, in claiming a place among the great industrial cities of this country.

This is the 22nd Semi-Annual meeting of this Society and bids fair to be one which we will not soon forget. I would like to say a few words about our development in the past and possibilities and hopes of the future. The Society was organized in the year 1894 with 75 charter members.

The first local Chapter to be formed was in Illinois in 1906 with 17 charter members. In 1911 the New York Chapter was formed with 64 charter members. In the year 1912 the Massachusetts Chapter was formed with 15 charter members. This year, the Eastern Pennsylvania, Ohio and Michigan Chapters have been formed.

The present membership of the parent body is now 705. There has been a noteworthy impulse of new members during the last three years. In 1914, we enrolled 69 new members; in 1915, 110 new members, and so far this year we have enrolled 109.

One of the most gratifying steps the Society has taken in recent years was the appointment of a permanent salaried secretary to devote all of his time to the Society work. This, of course, resulted in quite a heavy financial burden on the Society, but owing to the large increase in new members, we have been able to meet this additional expense. However, in my opinion, it is not a good policy to depend on such an unknown quantity as probable initiation fees to meet current expenses. It seems to me that the thing to do is to build up the membership to a point where the dues will offset the current expense and then start a sinking fund with the initiation fees to be used for research work.

The income from dues only at present amounts to $6,800 approximately, against an operating expense of approximately $9,700. This means that by adding 300 new members to the Society, these results could be obtained. Another way to accom-

plish the result would be to raise the annual dues, but notwithstanding the fact that the dues of this Society are lower than any similar society of equal standing, I would regret the necessity of increasing them; so let us all endeavor to bring our membership up to where it belongs.

Our Detroit members have given us a shining example of what can be accomplished and I wish to take this opportunity to congratulate them on being able to start their local Chapter with 52 charter members, 39 of which are new members in the parent body.

I think the establishment of local Chapters in the different cities should be encouraged, as it will afford the members a better opportunity to take an active part in the Society's work and will also assist in building up the membership of the parent body. It also enables the parent body to keep in closer touch with its members and their work locally.

We should have, at least, twelve to fifteen local Chapters, and each Chapter should be required to produce, at least, one paper at each meeting of the parent body. This could easily be accomplished by a little effort on the part of the members. A step in this direction, which, I think, would be of great assistance in this building up work would be the appointment of a local secretary to be the official representative of the Society in each city where no local chapter exists at present. Secretary Obert has already felt the need of these local secretaries. I am sure that these appointments would eventually result in local Chapters.

One other recent step of the Society which I wish to mention, is the publishing of a quarterly Journal, and I wish to take this opportunity to congratulate our Publication Committee on the success of this step. I am sure the Journal is fulfilling a long-felt want and I look forward to its soon becoming a monthly publication. We all owe our Publication Committee every support we can give both in articles for publication and in advertising. While we do not care to make a big feature of the advertising, still we should have enough to pay the expense of issuing the Journal.

Let us all get inoculated with a little of this Detroit "push" and I am sure we will get results far beyond our expectations.

PRESIDENT HART: We have with us an Honorary Member, who is an old resident of Detroit, and one whom you all have heard of, probably have read his publications and know who he is, but I do not suppose that many of the people in Detroit have had the pleasure of meeting him personally. I want to introduce Profes-

sor Baldwin and I would like to have him say a few words to his old neighbors of Detroit.

WILLIAM J. BALDWIN: I had no idea that your president intended to call on me, but perhaps when I tell you what I have been doing this morning, it will be nearly as good as making a speech.

The Moffat Block on Griswold Street was the first office building of any moment built in Detroit. It was built in 1870 and it fell to my lot to be the Engineer of it. I put the plant in it, embracing two 70 h.p. boilers, and about 6,000 sq. ft. of heating surface, two steam passenger elevators and one steam freight elevator. This building and the City Hall were the first two modern heating plants in Detroit.

I found the old elevators I put in, in 1870, still in commission and I had the pleasure of riding in them this morning. The passenger cars were the same, but they had changed the motive power from Otis steam engines to hydraulic. The old freight and safe elevator is running yet, with the old Otis steam engine in fairly good condition after 45 years of use. The present engineer says it would stand a little "fixing up."

The wonderful things Detroit has done since my time have surprised me. I was here for a few minutes since 1877, but no apparent changes of moment had taken place. The depot was at the same old place on the River, just where it was when they transferred passengers by boat, from train to train. But coming in this morning I was absolutely bewildered at the wonderful change and the wonderful growth, and I may say that though I went to a city that is pretty big (New York), I am sorry I did not stay in the "City of Straits." I think I would have been commercially better off if I had done so, considering the wonderful way the city has developed.

I want to express my appreciation of one thing in Detroit if nothing else, and that is the way they have of painting the "safety-zones" in the streets white, to keep people from being run over. I think they have done a wonderful thing here. We have a few streaks of whitewash in New York here and there to indicate where the cars are likely to stop (?), but nothing like the system you have here in Detroit. A person in Detroit can cross the streets with a maximum of safety and a woman can pause in the safety-zone when boarding a car, with more assurance than any other city in the world, I believe.

The time I spoke of (1870-77) I remained here seven years. To some of the older inhabitants, I will say that I was superintendent

of the Novelty Works of Detroit, which was just over the then City line, Hamtramck, north of Mt. Elliot Avenue, and the first radiators built in Michigan were built there. They were built under patents of a man named Walter Thompson. Mr. J. B. Dyer, who had a shop at the lower end of Woodward Avenue, was the next man that associated himself with the radiator business, and the first man to make cast iron radiators in Detroit.

I am not far wrong in the history of this subject and I feel I am right in saying that Mr. J. B. Dyer was the inceptor of the "Detroit Radiator," a cast iron radiator, put together with rubber washers at the top, when used for hot water. I have some of them in my house in Brooklyn to-day and they have never had to be repacked; the original washers are in place. I consider Detroit the parent city of *cast iron radiators*. I know that radiators of cast iron were made before, but not those that have survived, or of the pattern we now find all over the world. The general type made by the American Radiator Company and other American makers was first made in Detroit.

I don't think I should take the time now to say more about Detroit, but I am anxious to say that I knew Detroit first in 1866. I viewed it from the opposite side of the River. Our Civil War was just over and I took a job under the Great Western Ry. of Canada. I was a young naval architect then and was employed on the construction of the "Great Western"—one of the first, if not the first, iron ships, built on the Great Lakes—just above Walkerville, on the site of Ford's automobile factory at Ford City, Ontario. This was the first ferryboat to carry the Great Western railway trains across the Detroit River. Before that time passengers were transhipped on the old "Union," a wooden boat somewhat like the present ferryboats, but larger, that run between Detroit and Windsor and on which we had time to get our meals while crossing the river.

This old steam ferryboat, the "Great Western," was the first boat to carry a train of cars across the river and she is in commission to-day. Why would I not be fond of Detroit—the beautiful City of "The Straits" (*De'troit*).

THE PRESIDENT: The first in order of business is the announcement of a quorum (15 members). It is quite evident that we have a quorum so that we can proceed with the next in order of business—the annual reports of the Local Chapters. The first is the report of the Illinois Chapter. Is there anyone here prepared to read the report?

The report was read by the Secretary as published in the July issue of the Journal (see page 429 of this Volume).

THE PRESIDENT: The next will be the report of the Massachusetts Chapter. The report was read by the Secretary as published in the July issue of the Journal (see page 431 of this Volume)

THE PRESIDENT: The next will be the report of the Michigan Chapter by Mr. William F. McDonald.

WILLIAM F. MCDONALD: Detroit has for many years been known as the home of a few members of the Society, but last Fall it was decided that the opportunity was ripe for forming a Michigan Chapter. Nothing was done, however, until along in the month of February when, after Mr. McNair became a member, we partook of his hospitality at one of our clubs and then and there formed the Michigan Chapter and signed the application to the Council. We gave everybody an office and started out to get new members. We were rather successful in this, and, as a matter of fact, we have not taken all of the applications which have been offered to us. We did not feel exactly like crowding any of the larger Chapters just for the present and consequently thought we would limit our membership up to July 1st to something in the neighborhood of sixty. We overstepped ourselves, however, and have sixty-two. We have about ten or twelve applications for membership on hand and with fifteen or twenty more, it looks as if we will start the opening of the season in October with a membership of something like seventy-five. During the coming year we will most likely reach the hundred mark and in reaching the hundred mark, it is not with any desire of beating any other Chapter. It is simply a condition which exists here in Detroit, the opportunity of engineers assembling and forming a Chapter and doing each other a lot of good is at hand, and we are taking advantage of it. In doing our own members a lot of good we feel that we ought not be selfish and forget the Society at large, and I think we will eventually in this next year help the Society by making the Michigan Chapter a real live member.

The report of the Michigan Chapter was then read by Mr. McDonald as published in the July issue of the Journal (see page 432 of this Volume).

THE PRESIDENT: I think that we can all be proud of the start that the Michigan Chapter has made. I hope it will be an inspiration to not only other new Chapters but to the old Chapters as well.

We have next to hear the report of the New York Chapter. Is there any one here to read the report of the New York Chapter?

The report was read by Frank K. Chew of the New York Chapter, as published in the July issue of the Journal (see page 433 of this Volume).

THE PRESIDENT: The next is the report of the Ohio Chapter. Secretary Phegley of the Ohio Chapter is here and I would like to have him read the report.

The report was read by Mr. Phegley as published in the July issue of the Journal (see page 435 of this Volume).

THE PRESIDENT: The next is the report of the Eastern Pennsylvania Chapter. Is President John D. Cassell of Philadelphia Chapter present?

The report was read by President John D. Cassell, as published in the July issue of the Journal (see page 437 of this Volume).

THE PRESIDENT: We have heard the reports from all of the six Chapters and we will now hear the reports from special committees. The first is a report of a Committee appointed to attend the Conference on Engineering Co-operation which was held in Chicago April 13th and 14th, 1916. Mr. John F. Hale who is Chairman of the Committee, will present the report.

## REPORT OF COMMITTEE ON ENGINEERING CO-OPERATION

Your Committee, appointed by the President in March, 1916, to represent the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS in a Conference on Engineering Co-operation held in Chicago April 13-14, 1916, was in attendance at all of the sessions of the Conference, held in the assembly hall of the Western Society of Engineers and took part in the discussion, which resulted in a resolution, the wording of which is given herein. At the request of President Hart, the chairman of the committee submitted a brief statement to the Conference, giving the members a general idea of the objects and activities of our Society, which was as follows:

> "The AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS was organized in 1895, and has developed since that time into a society of over five hundred members, including professional heating and ventilating engineers, and representatives of such manufacturers as handle goods which require an engineering knowledge to insure the proper installation of their product.

"The object of the Society is the promotion of the arts and sciences connected with Heating and Ventilation in all branches, the maintenance of a high professional standard among its members, the reading, discussion and publication of professional papers which are calculated to advance the science of Heating and Ventilation—and the interchange of experience among its members.

"Two meetings are held each year, the annual business and professional meeting taking place in January, at the headquarters, located in the Engineering Societies Building, New York City, and a mid-year professional meeting usually taking place in July, in such city as may be selected by the Council.

"In such cities as the local membership will warrant, local Chapters have been organized, and at the present time these include:

Illinois Chapter, Chicago, Ill.
Massachusetts Chapter, Boston, Mass.
Michigan Chapter, Detroit, Mich.
New York Chapter, New York, N. Y.
Ohio Chapter, Cleveland, Ohio.
Eastern Pennsylvania Chapter, Philadelphia, Pa.

"Each Chapter holds monthly meetings from October to May, each inclusive, and the papers read and discussions thereon are reported upon at each summer meeting of the parent body.

"Papers read at the Chapter meetings must be referred to the Publication Committee of the Society and must be approved of by them before they may be published in the trade press or otherwise. Papers relating to the general subject of heating and ventilation may be prepared by any member of the Society, but cannot be presented to the Society without first having passed through the hands of the Publication Committee and approved of by them. The Publication Committee consists of three members of the Council, which together with all officers are elected by the members.

"In order to advise the members of the Society of papers to be read at a proposed meeting, such papers as have been approved of, are published in the quarterly Journal, a copy of which is sent to each member as published. This advance information enables the members to familiarize themselves with the subjects and be prepared to discuss the papers either

in person at this meeting, or by written discussion sent in in advance.

"The nature of the papers which have been discussed during the meetings of the past twenty-one years, cover practically every phase of the heating and ventilating art, not only the principles of design but standard requirements, the application of special appliances and devices.

"Great care is exercised in the restriction of papers and discussion which would tend to advertise or imply approval of any patented methods or construction, the attempt being to keep the standard of the Society as nearly professional as possible.

"Committees have been appointed from time to time and reports have been received with recommendations as to standards which the Society could establish, and a great deal of work has been done toward the establishment of a code for the proper ventilating of public and semi-public buildings.

"Our Society has co-operated with the Ventilation Commissions in Chicago and New York, and has worked with the Chicago Ventilation Department in the development of the code now in effect.

"The proceedings of each meeting, including papers read and discussed, together with all reports approved by the council or the members in session, are put into permanent bound volumes, a copy of which is furnished each member. Copies of these may also be found in the libraries of other engineering societies, and many engineering colleges.

"Co-operation between local chapters of the various societies represented at this meeting would undoubtedly be mutually beneficial, and national committees made up of members representing the various societies for the purpose of standardizing methods is recommended.

April 10, 1916.

The Conference on Engineering Co-operation was attended by representatives of forty-two national, state and local engineering and technical societies from all parts of the United States. The purpose of the Conference was to bring about a closer relation among engineers and engineering organizations, to discuss ways to improve standards of engineering practice and to gain a clearer recognition of the engineer as a civic asset. Mr. F. H. Newell, professor of civil engineering of the University of Illinois, was chairman and C. E. Drayer, secretary of the Cleveland Engi-

neering Society, was secretary of the Committee on Engineering Co-operation, which had the meeting in charge.

The program occupying two days, April 13th and 14th, consisted of the presentation of papers and addresses by delegates from the various societies represented. The subjects discussed were practicability and limits of co-operation, employment, ethics and legislation. Co-operation from the standpoint of the state society was presented by Paul Hansen, president of the Illinois Society of Engineers, and by Clyde T. Morris, President of the Ohio Engineering Society; from the standpoint of the national societies by P. Junkersfeld, of the American Institute of Electrical Engineers, Horace C. Gardner, of the American Society of Mechanical Engineers, DeWitt V. Moore, of the American Society of Engineering Contractors, John F. Hale, Past President of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, C. H. McDowell of the American Institute of Mining Engineers, and John Howe Peyton, of the Engineering Association of the South; from the standpoint of the local society by Ferd G. Gasche, of the Engineers Society of Western Pennsylvania, A. J. Himes, of the Cleveland Engineering Society, H. L. Keck, of the Dayton Engineers Club, and Lewis R. Ferguson, of the Engineers Club of Philadelphia. Short addresses were made by Isham Randolph, Onward Bates, John W. Alvord, and E. T. Perkins.

Employment was the subject of a paper by Arthur Kneisel, secretary of the American Association of Engineers. A. W. Hoffmann, of the Associated Technical Men, gave a paper, heard with marked interest, descriptive of engineering societies and their activities in Germany.

Legislation, with particular reference to recent experiences in Illinois, was discussed in a paper by H. J. Burt, of the Structural Engineers Society of Illinois. Delegates to the conference were entertained by the Chicago Engineers Club and at a complimentary luncheon at the Hotel Kaiserhoff, by Sub-division 63, Engineers of the Chicago Association of Commerce.

Other speakers told of the activities of the different engineering societies throughout the United States. This information contributed materially to an understanding of the problems before the conference.

The attached resolutions were unanimously adopted, which, it was suggested, should be published with "Spirit of the Conference," by Isham Randolph, preceding them.

### SPIRIT OF THE CONFERENCE

"Let us have a central organization—call it what you will—which has no authority to command, but which has ears to hear and the voice to be heard, and let those ears be open to every plea or promise of common good, and let that voice go out to all affiliated bodies carrying this plea or this promise for the common good, and let us come together at least once a year and feel that 'touch of nature that makes the whole world kin,' and growing out of that kinship let us consider and do those helpful things which will bless our comrades and overflow with helpfulness to our country and our kind."

BY ISHAM RANDOLPH

## RESOLUTIONS

WHEREAS, the rapid increase in engineering activity of recent years has given rise to many problems vitally affecting the practice of engineering, and

WHEREAS, existing agencies through lack of proper correlation appear inadequate for the solution of these problems, and in order that the resources of the profession may be made available for the most useful service to the nation, state and municipality, and that the practice of engineering may be rendered more efficient and less burdensome in those places where its development has been most difficult, and

WHEREAS, it is the sense of the Second Conference on Engineering Co-operation representing societies, national, state and local, and comprising various branches of engineering, that these ends may be attained throughout a closer association and co-operation of engineering societies,

BE IT RESOLVED: That there is hereby established a sub-committee with Mr. F. H. Newell as chairman and four other members to be selected by him, with instructions to prepare a plan for forwarding co-operation among engineering societies upon matters of general interest to the engineering profession, such plan to be presented for formal consideration at a third conference on Engineering Co-operation to be called by the sub-committee at such time and place as may seem to it desirable;

BE IT FURTHER RESOLVED: That the several organizations represented at this conference should be permitted to assist in defraying the expenses of the Committee on Engineering Co-operation and that the sub-committee should be requested to present to each of the societies represented an estimate of probable expenditures including clerical service, together with recommendations for equitable pro-rating;

BE IT FURTHER RESOLVED: That this conference express, its high sense of appreciation for the courtesies and hospitality extended by the Western Society of Engineers, Sub-Division 63 of the Chicago Association of Commerce and the Chicago Engineers' Club, and hearty thanks therefor are hereby expressed.

COMMITTEE ON RESOLUTIONS,

PAUL HANSEN, *Chairman.*
JOHN HOWE PEYTON,
ALBERT J. HIMES.

Resolutions unanimously adopted April 14, 1916, by Second Annual Conference of Committee on Engineering Co-operation.

C. E. DRAYER, *Secretary.*

We have been in touch with F. H. Newell, Chairman of the Co-operative Engineering Sub-Committee since the meeting in April and he informs us in a recent communication that they cannot yet give us a report of their work nor can your committee at this time advise the Society as to the financial assistance which they may expect.

We recommend that the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS secure permanent membership in this Engineering Co-operation organization and that reasonable financial assistance be given.

Respectfully submitted,

JOHN F. HALE, *Chairman.*
SAMUEL R. LEWIS,
DR. E. V. HILL.

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THE PRESIDENT: This report requires some action by this body. As near as I understand, it is the desire of this Co-operative Engineering body to have the membership comprised of representatives of various engineering organizations and it would become necessary for this Society to vote to join with them and for the Chairman to appoint a committee to attend their meetings. A motion will be considered.

FRANK K. CHEW: I move that it is the sense of this meeting that the recommendations of the Committee be referred to the Council, for favorable consideration. I think that is as far as we can go.

JOHN F. HALE: I second that motion. That is a very good idea.

WILLIAM G. BALDWIN: That will leave no option except favorable consideration. Why not strike out the word "favorable"?

FRANK K. CHEW: If we do not put the word "favorable" in there, how will this Council know what we have done? We have not expressed ourselves here that we are favorable to the thing. The Council has the power to do whatever it thinks is best.

WILLIAM G. BALDWIN: At the same time their report must be favorable, if we are in favor of it. Mr. Hale, have you any idea what the expense would be—one hundred dollars?

JOHN F. HALE: I have not the slightest idea and the Committee could not give me an idea. I tried to learn on two occasions; they said they had met, but had not been able to get together.

The point is that it is not a question of paying the expense that they have already gone to, but the expense that they may be put to in developing this thought. Their idea was somewhat exaggerated, I thought, at the time, as they had a feeling that they wanted to publish a journal for the purpose of getting all the benefits for all of the engineering organizations that were possible; to get the members thinking along the right lines and to have us thinking "engineering" instead of "heating engineering"; for us all to think of engineering as a profession and to talk "engineering" and not simply to talk our end of it; to place the profession on a higher plane so that the public will understand that when an engineering problem is to be put up to people professionally, it will be to people who understood the subject; that if they hire a professional engineer to do the work, that at the end that organization will back the subject up.

FRANK K. CHEW: I get this conception of that organization that as far as possible they intend to card-index the engineers of the United States so that if one is doing civil engineering work and is better qualified for heating and ventilating engineering, his list of qualifications filed with the organization will enable them to recommend him to something to which he is better qualified.

JOHN F. HALE: That is one of the thoughts purely incidental to the rule that is back of it, but the main thought is to enlarge the scope of the engineer.

FRANK K. CHEW: In other words, the ethics of the engineer to-day has gone up but it is not advertised.

FRANK K. CHEW: I will leave the motion as I made it, Mr. President.

JOHN F. HALE: That is the idea.

THE PRESIDENT: The motion is that the report be referred to the Council, with a request for favorable consideration. The motion has been made and seconded; is there any further discussion before I put the question?

(There was no further discussion and the motion was carried.)

THE PRESIDENT: Next will be received the report of the Committee on The Best Position for a Radiator in a Room, W. F. Verner, Chairman. Is Mr. Verner, or any other member of the Committee, present to read that report? If not it will be read by the Secretary.

The report was read by the Secretary as published in the July issue of the Journal (see page 441 of this Volume). Following this, it was discussed by A. S. Armagnac, J. F. Hale, William J. Baldwin, J. A. Donnelly and H. M. Hart. A motion was then made and carried that the question be referred back to the Committee for further experimentation and report.

The session then adjourned for luncheon.

SECOND SESSION—WEDNESDAY P. M., JULY 19, 1916

THE PRESIDENT: The next in order is unfinished business. As there is no unfinished business, we will proceed to new business. Has anybody anything to offer under the heading of new business?

FRANK G. PHEGLEY: There is one point that has come up to my mind. Mr. Chew told us this morning that the existence of the Society depended largely on the success of the Chapters and I believe that has been proven, due to the fact that since the Chapters have been organized there has been a large influx of membership to the Society, and it is through the Chapters' efforts that these members have been brought into our fold.

Now, if it is true that the Chapters are going to be the upholding feature of the Society, it appeals to me and to the Ohio Chapter, that each Chapter should have some jurisdiction over a particular territory, and to secure an expression from the Council I wrote the Secretary calling attention to the fact that there were certain members of the Society in the city of Toledo who would prefer, due to the nearness of Toledo to Detroit (being one hour nearer by railroad than Cleveland), to join the Michigan Chapter. They would probably get a great deal more benefit out of that affiliation, than to join the Ohio Chapter. But I felt that inasmuch as the Ohio Chapter, at Cleveland, had already some members in the city of Toledo, that the Council should give us some jurisdiction over some

allotted territory so that the other Chapters could not come in and take our material without our knowledge.

I do not mean to say that the Ohio Chapter would stop the affiliation of any member in the state of Ohio with any other Chapter if that particular member felt that Chapter was a better affiliation for him, but we would like to know it and I think every Chapter would like to know what their material is and what they intend to do, so that they can get a chance to talk to them.

It seems to be a vital question. We are trying to build up something in Ohio. We admit that Detroit is superior to us in heating and ventilating engineering. It is due, perhaps, and I believe wholly so, to the nearness of Ann Arbor and particularly Prof. Allen. He turns out engineers there in the heating and ventilating line; they come to Detroit possibly first and follow the profession there.

We have a school, the Case School of Applied Science, equally as good, from a mechanical engineering standpoint, perhaps, as Ann Arbor, but they do not follow the line of heating and ventilating engineering. The Ohio Chapter is trying to interest Prof. Howe of the Case School of Applied Science, and just a few months ago I spent two hours with Prof. Howe advising him of the interest Prof. Allen has taken in this branch of the art and I believe he will try to follow Prof. Allen's ideas in the Case School of Applied Science.

The main point I want to bring before the Society is as follows: Is it not policy that each Chapter have jurisdiction over a certain territory?

When I wrote to the Secretary the matter was referred to the Council and they gave us a reply that the Chapter had jurisdiction over nothing. What is the use then of the Chapter spending its time trying to build up an organization when the Council can come back and throw our building over?

There is another question in the mind of the Ohio Chapter and that is the idea of the proposed corresponding secretaries. It seems from the explanation Mr. Obert gave me, that these secretaries will be appointed in different cities and will report back direct to the Council through the Secretary. It appeals to us that these corresponding secretaries should be under the jurisdiction of the Chapter and the Chapter in turn report back to the Council, thereby giving the Chapter some legitimate status of its own.

I want to get other Chapters thinking of the subject and perhaps they can express themselves as to what they think of it.

FRANK T. CHAPMAN: I would like to know what the Council's report was.

The letter was quoted as follows:

July 15, 1916.

Mr. F. G. Phegley, Secy.,
Ohio Chapter, A. S. H. & V. E.
Cleveland, Ohio.

Dear Sir:—Your letter relating to jurisdiction of Chapter organizations came before the Council of the Society on May 24, 1916, and was referred to the Executive Committee for suggestion. The suggestion of the Executive Committee, as later approved by the Council is as follows:

It is the sense of the Council that any member of the National Society is entirely privileged to apply for membership in any Chapter he may wish, in or out of his resident State and consequently the only method the local Chapter should have to induce associates to become members of the local branch, would be by persuasion. It is held that the method you suggest of applying jurisdiction privileges would tend to create friction and therefore be against the interest of the Society as a whole. Toledo being only one half the distance from Detroit that it is from Cleveland, members residing in Toledo might easily feel that they could more often be able to attend meetings in Detroit than in Cleveland and against this you would find a certain feeling of loyalty to Ohio. There could be of course no objection to a resident Society member of Toledo becoming a member of both Detroit and Cleveland Chapters.

Mr. Obert also states that on his recent visit to Cleveland, the question came up as to the possibility of there being more than one Chapter in a State and covering this point would say that the fact that the National Society grants a charter to a local Chapter in any State does not necessarily prevent another Chapter being formed in the same State, provided the forming of such other Chapter would advance the Society's interests. A case at point might be New York City and Buffalo in the State of New York. There is of course the New York Chapter with headquarters in New York City, but this does not prevent a Chapter being formed in the City of Buffalo, provided there were found to be members enough and interest and demand enough to form such a Buffalo Chapter.

Trusting you will find upon reviewing the situation that the above position is the only reasonable one which could be very well maintained and trusting that you will be able to satisfactorily overcome the objection on the part of some of the Ohio Chapter members, I am,

Very truly yours,

Chairman, Executive Committee.

FRANK G. PHEGLEY: The reply in substance is that all these matters are to be handled directly by the Council and that the Chapter is to have no jurisdiction on territory or practically anything else; that we are just an organization of a few men to talk over heating problems and are not really a part of the Society.

THE PRESIDENT: I think Mr. Phegley has the wrong idea. The Council's attitude is that the Chapters are formed for the benefit of the members and it is the desire that the members join where they can get the most good. There is no use compelling a member to join a Chapter 500 miles away, because he happens to be in that state, when he can just as well join a Chapter 100 miles away, that is just across the border and there is some chance of him attending the meetings there and obtaining some good from association with the Chapter.

The letter is to the effect that before any member of one state was admitted to membership in another state, or a foreign Chapter, the Chapter in his state should be notified and given an opportunity to talk to this member and if they could persuade him that he would receive as much benefit from joining their Chapter as by joining the other one, why all well and good. But there is nothing in our Constitution or By-Laws which would compel or restrict any member joining a local Chapter or to confine himself to any particular district. As far as our By-Laws are concerned, a Chicago man could join the New York Chapter if he wants to.

I do not see that the Council could have taken any other course, unless you want to change the By-Laws and establish a rule. If you want to change the By-Laws governing that point, you will have to follow the regular procedure for offering a change of By-Laws; the petition must be signed by at least three members and presented at a regular meeting.

We were not trying to work a hardship on the Chapters, but were trying to *avoid* working a hardship on the members. It would not be any benefit to a Chapter to compel a member to join in one location where he did not want to join, because he would not attend the meetings.

THE PRESIDENT: Next we will proceed with the reading of the papers and the first one on the program is: "Tests of Fractional Valves," by James A. Donnelly.

I might say, in explanation, that the Committee on Tests was requested to submit a report on fractional valves, but for various reasons the sub-committee did not seem to get together, and so Mr. Donnelly went ahead and wrote a paper on the subject, so

that something would be presented at this meeting for the purpose of bringing out discussion. This is something we are all interested in and there is nothing on the subject in our files. I do not know where there is anything on record which is authentic on fractional valves.

The paper was read by the author, Mr. James A. Donnelly, as published in the July issue of the Journal (see page 453 of this Volume). It was discussed by John F. Hale, Wm. J. Baldwin, the Author, H. M. Hart, R. L. Gifford, and F. K. Chew.

THE PRESIDENT: The question was asked in the Council whether a paper should be presented to this Society without the signature of the writer of the paper. The reason it was asked is this: Some members are, perhaps, very modest, and do not want their names to appear too often in the Society work; they do not want people to think that they are seeking too much prominence. Another thing is that some members are very well versed on certain subjects, which they could give us some very good data on, but they are so situated in their lines of business, that they do not feel free to come right out with an article over their signature and have it published broadcast. So we have said: "Yes, any member who wishes to produce a paper and sign it 'By a Member,' can submit it if he will give the Council his name, and it will be published if accepted." The result was that we have two papers on this afternoon's program signed "By a Member." The first one is: Clean, Pure Air for our Cities, by a Member.

The paper was read by the Secretary as published in the July issue of the Journal (see page 471 of this Volume). It was discussed by Wm. J. Baldwin, L. C. Soule, E. L. Hogan, J. R. Allen, and H. M. Hart.

THE PRESIDENT: Next we will go on to the paper entitled: Commercial Drying Apparatus, by L. P. Dwyer. Mr. Dwyer is not a member of the Society, but has done considerable work in commercial drying, and at my request, has kindly consented to give us a paper on this subject.

The paper was read by the Secretary as published in the July issue of the Journal (see page 479 of this Volume). It was discussed by A. S. Armagnac, Fred R. Still, and H. M. Hart.

THE PRESIDENT: The next is a paper entitled: Heat Transmission Calculations. by a Member, who has taken advantage of the privilege.

The paper was read by the Secretary, as published in the July issue of the Journal (see page 487 of this Volume. It was discussed by William J. Baldwin,

M. W. Ehrlich, Wm. F. Verner, Fred R. Still, H. M. Hart, A. S. Armagnac, and J. A. Donnelly.

THE PRESIDENT: The next paper is on the Ventilation of Garages, by C. W. Obert.

The paper was read by the Author, as published in the July issue of the Journal (see page 499 of this Volume). It was discussed by Fred R. Still and H. M. Hart.

The session then adjourned until the following morning, at the University of Michigan in Ann Arbor.

### THIRD SESSION—THURSDAY. JULY 20, 1916

(Held in Engineering Building, University of Michigan, Ann Arbor)

THE PRESIDENT: The first paper this morning will be that on Heat Transmission through Building Materials, by Prof. J. R. Allen.

The paper was read by the Author, as published in the July issue of the Journal (see page 507 of this Volume). It was discussed by H. M. Hart, M. W. Franklin, J. J. Blackmore, E. A. May, J. A. Donnelly, F. W. Johnson, C. A. Blaney, A. S. Armagnac, Wm. J. Baldwin, W. F. Werner, Thos. R. Wooley, F. H. Valentine and the Author.

THE PRESIDENT: We will pass on to the next paper, which is entitled: Notes on the Testing of Warm Air Furnaces, by R. W. Davenport.

The paper was read by the Author, as published in the July issue of the Journal (see page 527 of this Volume). It was discussed by Prof. J. R. Allen, W. F. Verner, the Author and Frank K. Chew.

(After this, the session adjourned for luncheon in the Gymnasium, the organ recital in the Hill Auditorium and the visit to the new University power plant and heating tunnels, resuming at 2.30 P. M.)

THE PRESIDENT: We have only one paper this afternoon but I am sure it is an exceedingly interesting one. It is entitled: Co-efficient of Friction of Air Flowing in Round Galvanized Iron Ducts, by Prof. J. E. Emswiler.

The paper was read by the Author, as published in the July issue of the Journal (see page 537 of this Volume). It was discussed by J. R. McColl, J. R. Allen, W. F. Verner, J. J. Blackmore, H. M. Hart, and the Author.

After this, the meeting adjourned until Friday morning in the Convention hall at headquarters in Detroit.

FOURTH SESSION—FRIDAY, A. M., JULY 21, 1916

THE PRESIDENT: The first paper on this morning's program is that on: Engineering and Cost Data relative to the Installation of Steam Distributing Systems in a Large City, by F. H. Valentine.

The paper was read by the Author, as published in the April and July issues of the Journal (see page 547 of this Volume). It was discussed by R. S. Mayer, H. M. Hart, W. F. Verner, and the Author.

THE PRESIDENT: We will now proceed to the next paper on the program entitled: Heating a Conservatory and Greenhouse, by Prof. J. D. Hoffman.

The paper was read by the Secretary, as published in the July issue of the Journal (see page 565 of this Volume). It was discussed by J. J. Blackmore, E. A. May, H. M. Hart, and Frank K. Chew.

THE PRESIDENT: The last paper on the program is: The Effect of the A. S. M. E. Boiler Code on Heating Boilers, by C. W. Obert.

The paper was read by the Author, as published in the April issue of the Journal (see page 573 of this Volume). It was discussed by J. D. Cassell, E. A. May, John C. McCabe, H. M. Hart, E. F. Glore, J. J. Blackmore, and the Author.

THE PRESIDENT: There is one good old faithful member that we have missed at this meeting, and I find that he has sent a message regretting his inability to attend on account of illness, and extending a hearty greeting to all. That is Mr. Jim Davis, of the American Radiator Company, whom most of us know, and I am sure that we all miss not seeing him amongst us.

We also have two telegrams from members who are unable to be present:

New York, July 19, 1916.

President American Society of Heating and Ventilating Engineers,
Hotel Statler, Detroit, Mich.

Regretting my inability to be present at the summer meeting, I beg to extend to you and all members present my sincere wishes for a successful and pleasant convention.

REGINALD PELHAM BOLTON.

Knoxville, Tenn., July 19, 1916.

Secretary American Society of Heating and Ventilating Engineers,
Hotel Statler, Detroit, Mich.

Southern floods prevented my being with you at the convention. Regret I cannot add my help towards the good work you are privileged to do at your summer meeting. Here is hoping that you have a profitable meeting and enjoyable time. I congratulate the committees for their elaborate arrangements.

THEODORE WEINSHANK.

THE PRESIDENT: The regular order of business of this meeting is now finished. If any one has anything to offer for the good of the Society, we would be pleased to consider it. I want to offer one suggestion. We are now publishing a quarterly Journal, which I think is a credit to the Society. The Publication Committee has worked very hard on this Journal and they are entitled to the hearty co-operation and support of all the members. We cannot expect a Committee to work without pay and devote their time to publishing a Journal for our benefit—they must have some support. Our ambition is to see this a monthly Journal and that is going to inflict additional hardships and work on this Committee. I would like to see the individual members display interest in this Journal, display an active interest by giving the committee material to publish articles that would be of interest to the members; and if they can help out in the advertising end at all, that would be appreciated also; there is considerable expense involved in connection with publishing this Journal, and we would like to make it self-supporting, if we can.

But we would like to have a little more material from the members. We want them to be interested in this Journal, and when they have something that would be of interest to the members, send it down to the Publication Committee. Let the Society get the benefit of it, and I am sure you will receive due credit for anything that you give along that line. If you are so situated that you might lose your job if you criticize something that your office is doing, we will accept the paper and publish it as if issued—"By a Member."

W. F. VERNER: Is it within the power of the Publication Committee to change the title of any of the papers after the papers are presented? We sometimes find that what is contained in the paper is not very well covered by the title. I have found in my own experience, in looking through an index, references to certain items and when I would refer to the articles, I would not find what I wanted. The titles have sometimes been very misleading. For an example would be this case where we have the subject: Clean, Pure Air for our Cities. That paper deals primarily with a method of removing cinders and I think it should have a different title, so that a person investigating pure air for cities would not have to go all through that article and then perhaps find that it was not what he was looking for.

Would it not be possible for the Committee to look through the Journal and make up a good index of what we have, and get that out as a supplement, say, at the end of the year?

THE PRESIDENT: The subject of an index is one that has been considered by the Council and Secretary Obert tells me that it is practically finished.

The question of titles that you bring up, is a very good point. We will ask the Publication Committee to give the subject careful consideration, to remember that it is going to be indexed, and if they think that they could improve on the title of the paper, I think it would be well for them first to communicate with the author of the paper and get his consent.

FRANK K. CHEW: As a matter of fact in the past, the editor of the proceedings has taken that liberty for the benefit of the Society. That is what the paper is for, and when it adds to the benefit of the Society to change the title to say what it really covers, the editor has in former times, without consulting the board of governors, or anybody except the author, out of deference and decency, changed the title. That is a matter of record.

E. A. MAY: I do not think the proceedings would be quite complete without a rising vote of thanks to the members of Michigan Chapter and the members of the Entertainment Committee of this Chapter, who have so cheerfully given their time and attention to making this the most enjoyable meeting that I have had the pleasure of attending. I therefore move you that a rising vote of thanks be tendered the Michigan Chapter of THE AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS.

FRANK K. CHEW: I want to second that motion, but I want to go a little bit further. I think what the Michigan Chapter has done in the short time it has been in existence, is really an incentive for the whole Society. Rather, it is something more than an incentive—it seems to me that it lays down a duty and an obligation for us others to get as busy as they have been here. Detroit is not the only town that has got a good many engineers in it that should meet together for the common good, not only for the local men, but for the whole Society. So we find in the delightful hospitality which is so gracious that you enjoy it without knowing that you are getting something that you never had before at a summer meeting, we find here an example of what *can* be done, and it is something for every member of the Society to be proud of.

This meeting here has been better as the result of the systematic and careful manner in which they have thought about what they are going to do for some time. I want to say that what has been done here is a lesson for the New York Chapter which has had

the pleasure and the honor, as well as the considerable responsibility, of entertaining the Society at the Annual Meetings. I stand here converted from the idea that a man comes to the Annual Meeting with the idea of getting technical information only. I have learned here that the outside convention and outside information is quite as important, if not more important, than what you get here on the floor. It enables men to meet together and there is a splendid social spirit that has been manifested here which enables men to get from each other what they won't get on the floor. Many men are not of the kind that exchange ideas on the floor of the convention, but at this meeting these men have been together, they have talked together in the cars and they have never talked as freely as they have at this meeting, due to the atmosphere created by the Michigan Chapter.

Now, we won't get all that they have given us, if we don't take home with us that same spirit. I want to say as Vice-President of the New York Chapter, that I feel this a little more severely by reason of the fact that I reported for the New York Chapter that our Chapter does not get together and work as this crowd does. They say a new broom sweeps clean; it *does* sweep clean in proportion to the quality of the broom. I take off my hat to the quality of the broom used by the Michigan Chapter.

THE PRESIDENT: I wish to thank Mr. May for offering this suggestion and Mr. Chew for helping me out in expressing the personal feelings of all the visitors at this convention. There is very little that remains to be said, but before putting the motion, I want to add a few words for the benefit of the members who are going to profit by the example set by the Michigan Chapter. Some of us may feel that in offering membership in this Society as a possibility to some of their acquaintances, that their acquaintances may come back and say: "Well, what great work has this Society been doing? I do not see that they have done very much, although they are holding meetings all the time."

Sometimes I have been stumped myself to give an immediate reply, because I have had the experience that has been given on the floor, that when I want to get hold of some tangible result of the work in our records it has been rather hard to find. But, *good work has been done* by this Society, and better work can be done, and we want more material and good material. My argument is this: That we want these good men to come in here, not to criticize the Society, but to work and *help us work*. There is work that has to be done and we need all the help that we can get.

These members are not invited to come into the Society for what they are going to get out of it, but they are invited to come into the Society for what the Society is going to get out of it, and if it is put up in that way I believe you will get good results.

(The motion for the vote of thanks was carried, and the members and guests present responded unanimously to the call for a rising vote.)

FRANK K. CHEW: Referring to what the Society has accomplished, I want to say that at the tenth anniversary meeting, Past President Stewart was given the task of telling what had been achieved by the Society in the first decade of its existence. I cannot remember all that he said, although I was delighted and surprised at the time at the progress that had been made in bringing this from a small organization in Philadelphia down to what it is now. I think he said at that meeting that at the time that the Society was brought into existence, the method of computing radiation was largely 1-40th or 1-50th, and that the Society had brought about means of determining the actual amount of radiation required in a much more scientific way. There is no question about this, and I am safe in saying that the early work of this Society in the first five years, was the means of perfecting fan construction. Another thing is that where manufacturers in the past didn't give out what they call their "inside data," it is now made accessible.

So far as this Boiler Code Committee is concerned, our Society has done good work. We have a capable Code Committee where the brains of the boiler making business was reflected; that committee was heard very carefully and great deference was paid to it. The Society has also established an altruistic feeling towards the men in the field in respect of the labor element.

J. J. BLACKMORE: The altruistic feature of belonging to this Society is not considered nearly as much it should be. Don't you know that in giving up something for the general good you will get more real satisfaction than you would in making dollars? The fact that you have contributed something to help along the field of Heating and Ventilating Engineering will be a lasting source of satisfaction to any one who accomplishes anything good.

As regards the necessity for a larger membership, the industry has grown much more rapidly than this Society has grown. If this Society is going to be helpful to the industry, a larger proportion of those who are engaged in the industry and the engineering end of it should belong to it, and those who are not in the engineering end of it should give us their assistance by taking an asso-

ciate membership in the association. Each member should do all he can to induce those who are engaged in the industry to become members. A little concerted effort on the part of all the members would duplicate the work that has been done in Detroit and would bring the membership up to 1,500 inside of two years.

(The meeting adjourned until the Annual Meeting in New York, January, 1916.)

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## MEMBERS AND GUESTS

### PRESENT AT

### SEMI-ANNUAL MEETING, DETROIT, MICH., JULY 19-21, 1916

### MEMBERS

Allen, J. R.
Armagnac, A. S.
Baldwin, Wm. J.
Benbrook, A.
Blackmore, J. J.
Blaney, Chas. A.
Bolton, Jas. R.
Boomhower, F. K.
Braemer, W. J.
Bristol, H. D.
Brown, W. G.
Byson, L. L.
Calvert, N. W.
Capron, E. F.
Cassell, J. D.
Chapman, Frank T.
Chew, Frank K.
Claffey, E. J.
Collamore, R.
Connell, R. F.
Coon, T. E.
Cripps, A. G.
Crowall, M. L.
Cutler, J. A.
Davenport, R. W.
Degan, J. E.
Donnelly, Jas. A.
Downs, E. L.
Dunham, C. A.
Ellis, H. W.
Firestone, J. F.
Foster, Wm. M.
Franklin, M. W.
Fuller, J. L.
Gifford, Robt. L.
Glore, E. F.
Gottwald, C.
Graves, W. B.
Hale, John F.
Hamlin, H. A.
Harrigan, Ed. M.
Harris, E. E.
Hart, H. M.
Hayes, T. D.
Hill, N. J.
Hogan, E. L.
Hynes, T. F.
Johnson, F. W.
Jones, Robt. Ross
Knight, A. B.
Lillie, E. C.
Lindeblad, A. S.
Lindman, R. H.
Locker, Chas.
Lomasney, E. J.
Little, E. R.
McElfatrick, J. T.
McColl, J. R.
McDonald, W. F.
McNair, E. E.
McSorely, C. M.
May, E. A.
Mayer, R. J.
Mayer, R. S.
Nelson, B.
Newport, C. F.
Noland, R. W.
Obert, C. W.
Peck, C. J.
Petherick, D. H.
Phegley, Frank G.
Pittelkow, A. G.
Polk, G. C.
Robinson, W. J.
Sanborn, E. W.
Soule, L. C.
Stark, E. A.
Still, Fred R.
Stockwell, W. R.
Tuttle, J. F.
Valentine, F. H.
Van Sickle, W.
Walker, J. H.
Walton, H. L.
Wheeler, C. W.
Whitcomb, L. A.
Whitelaw, H. L.
Wigman, J. B.
Wilde, R.
Williams, J. W.
Woolfenden, John J.
Woolley, T. R.

## GUESTS

Beckwith, C. F.
Booth, H. N.
Burquest, W. H.
Carrabin, Thomas M.
Chester, T.
Craig, R. T.
Craig, T. F.
Deen, R. B.
DeLand, R. J.
Dill, J. B.
Emswiler, J. E.
Farleye, J. W.
Farrer, C. W.
Fitzgerald, F. B.
Gow, A. P.
Gurney, J. A.
Hackett, C. P.
Harms, Wm. T.
Henwood, N. A.
Hillis, W. S.
Howard, S. W.
Hughson, H. H.
Jolliffe, A. H.
Judson, E.
LaFollette, B. E.
Lanning, E. K.
McCabe, John C.
Milward, R. K.
Pearce, H. V.
Ross, A. H.
Rozier, P. V.
Singer, Frank J.
Skinner, Wm. C.
Slaughter, C. H.
Smith, R. G.
Snell, E.
Stimpson, G. K.
Thayer, W. H.
Trombley, J. H.
VanSickle, H. C.
Veal, C. B.
Vitalius, Edward H.
Webb, J. B.
Wilcox, G. D.
Wilson, T.
Wood, Geo. W.

## LADIES

Mrs. R. Collamore
Miss E. F. Connell
Mrs. R. F. Connell
Mrs. S. W. Ellis
Mrs. C. Gottwald
Miss E. A. Gottwald
Mrs. C. Hackett
Mrs. J. S. Hale
Mrs. H. M. Hart
Mrs. T. F. Hynes
Mrs. A. B. Knight
Mrs. R. W. Noland
Mrs. C. W. Obert
Mrs. F. G. Phegley
Miss Myrtle J. Phegley
Mrs. W. J. Robinson
Mrs. J. H. Valentine
Mrs. H. C. Van Sickle
Mrs. W. B. Van Sickle
Mrs. C. W. Wheeler

## No. 414

# ANNUAL REPORTS OF THE CHAPTERS

## ILLINOIS CHAPTER

THE practice of the Illinois Chapter is to hold its first meeting on the second Monday in October, and following that regular monthly meetings on the second Monday of each month up to and including May, when meetings are discontinued until the following fall.

The October meeting is customarily devoted to the election of officers and receiving reports of the past year's activities. At the October meeting in 1915, the Society was presented with a leather bound copy of the proceedings of the Chicago Commission on Ventilation. A somewhat formal discussion as to the advisability of licensing ventilating contractors in the State of Illinois took place.

At this meeting the following officers were elected and installed:

*President,* E. L. HOGAN,
*Vice-President,* F. W. POWERS,
*Secretary,* W. L. BRONAUGH.
*Treasurer,* AUGUST KEHM,

*Board of Governors,*
H. M. HART,
H. R. LINN,
C. F. NEWPORT.

President Hogan announced that he would endeavor to obtain outside talent to address this Chapter for a number of its meetings, and in pursuance of this policy, Mr. W. L. Abbott, chief engineer of the Commonwealth Edison Company gave us a most interesting discussion at the November meeting on "Power Plant Development of the Edison Company." Mr. Abbott informed us that his company would have in service, during the fall of 1915, 400,000 h.p., that the average daily consumption of fuel in the power houses of the Edison Company was one hundred carloads; that the Edison Company had in tránsit between mines and Chicago at all times at

Presented at the Semi-Annual Meeting of THE AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Detroit, Mich., July, 1916.

least 2,000 carloads of coal. Mr. Abbott's description covered the boiler plant and turbine plant.

At the December meeting of the Chapter we were addressed by Mr. Frank F. Cauley, manager of the Industrial Appliance Division of the People's Gas, Light & Coke Company. Mr. Cauley surprised the members of the Chapter by showing the wide application of gas for industrial purposes.

Mr. Byron T. Gifford of the American Public Utilities Company, Grand Rapids, Mich., addressed the Chapter on January 10, 1916, on "Central Station Heating." Mr. Gifford convinced the members of the Chapter as to his knowledge on this subject, by giving actual data from the plants at La Crosse and Indianapolis. Mr. Gifford made a plea to the members of the Chapter to be careful of their installations in buildings to be connected up to Central Station Plants, as the greatest enemy to Central Stations was the poor installation of the individual heating plant.

At the February meeting, the Chapter was entertained with a talk, illustrated by moving pictures, showing the work done by the Underwriters' Laboratory towards decreasing the losses from fires.

The March meeting was addressed by Mr. Elmer W. Rietz of the Chicago Car Heating Company, and by Mr. D. I. Cook of the Vacuum Car Heating Company.

The April meeting was addressed by Mr. Thomas C. McKee on "Refrigeration in connection with Artificial Heating," and by Mr. Ben Nelson, a member of the Chapter, on "Cooling with Air Washers without Artificial Refrigeration."

It would be very difficult to specify which of these meetings was the most interesting and instructive. At the February meeting, through the courtesy of James A. Donnelly, each member present was presented with a fine Spitzenburg apple; the members voted the Chapter's thanks to Mr. Donnelly for his courtesy.

During the year the following were elected to membership; J. F. Hale, G. H. Henrich, and G. D. Hoffman; and to associate membership: R. H. Lindman, and H. J. Gilson.

The May meeting was turned over to a good-fellowship Meeting, and was in honor of Mr. C. W. Obert, the national secretary who visited the Chapter at that time. At this meeting the Chapter introduced thirty-nine guests, who were invited as being properly qualified to become members in the parent body. No routine business was transacted, with the exception of calling the roll, and the entertainment was furnished by cabaret performers, under the leadership of the Chapter's star entertainer, Mr. Ray Stackhouse.

W. L. BRONAUGH, *Secretary.*

## MASSACHUSETTS CHAPTER

The first meeting of the year was held Wednesday evening, October 13, 1915, and officers were elected for the year as follows:

*President,* HON. E. R. STONE,
*Vice-President,* FRED S. BOLTZ,
*Secretary,* CHARLES MORRISON,
*Treasurer,* WM. T. SMALLMAN.

*Board of Governors,*
WILLIAM G. SNOW,
FRANK IRVING COOPER,
JAMES W. H. MYRICK.

At this meeting a change in the By-Laws was adopted, changing the annual meeting of Massachusetts Chapter from October to May of each year.

The November meeting of the Chapter was largely attended, the feature of the evening being an illustrated lecture by William G. Snow on the subject of Vacuum Heating. The December meeting was devoted to a discussion of general engineering topics.

The January meeting was suspended, to avoid interference with the Annual Meeting of the national Society in New York. The February meeting was devoted to a paper on The Early Experience of the Paul System, by Andrew G. Paul.

At the March meeting, the subject of the paper of the evening was: "Velocity of Flow in Heating Risers and Mains." The April meeting was devoted to general topics.

The May meeting resulted in the election of officers for 1916-17 as follows:

*President,* FRED S. BOLTZ,
*Vice-President,* WM. W. UNDERHILL,
*Secretary,* CHARLES MORRISON,
*Treasurer,* WILLIAM T. SMALLMAN.

*Board of Governors,*
FRANK IRVING COOPER,
WILLIAM G. SNOW,
EUGENE R. STONE.

Present membership of the Chapter, fifteen.

CHARLES MORRISON, *Secretary.*

## MICHIGAN CHAPTER

Detroit has for many years past appeared in the Year Book as the address of a few members of the Society, but it appears now as the home of the Michigan Chapter. The necessity of forming a Chapter with headquarters at Detroit, was discussed in October, and several applications for membership in the Society were secured at that time, but the application for a charter was not made until February. It was not then expected that much could be done this year except to get a start and have everything ready for the opening of the new year in October.

The Michigan Chapter now has, however, a membership of 52, and has 10 applications in hand. Preparations for the Summer Meeting have prevented securing signatures to nine more applications, which will make the total membership at the opening of the new year not less than 70.

A meeting was held on Feb. 5th, when the following officers were elected:

| | | |
|---|---|---|
| *President,* | PROF. JOHN R. ALLEN, | *Board of Governors,* |
| *Vice-President,* | FRED R. STILL, | W. F. FOSTER, |
| *Secretary,* | WILLIAM F. MCDONALD. | E. E. MCNAIR, |
| *Treasurer,* | EDWARD M. HARRIGAN. | A. G. PITTELKOW. |

The application for a charter for the Michigan Chapter was signed at this meeting, and Committees were then appointed to secure additional applications.

On March 6th, the members of the Chapter entertained the applicants at a dinner at which Prof. John R. Allen presided.

A meeting was held on April 6th with an attendance of 48. The subject for discussion, Heat Losses From Building Structures, was interestingly treated by Prof. John R. Allen, and the discussion following led by J. R. McColl, F. K. Boomhower, J. H. Walker and R. W. Davenport. Committee reports were received and an invitation to hold the Summer meeting at Detroit sent to the Council of the Society.

The next meeting was held on May 9th, with an attendance of 49, when Mr. Elmer W. Rietz of the Chicago Car Heating Co., read a paper on Railroad Car Heating, which was so instructive that all concluded that complaints on poorly heated sleeping cars are avoidable. Word was received at the meeting that the Council had acted favorably on the invitation of the Chapter to hold the Summer Meeting at Detroit on July 19-21. Mr. C. W. Obert, the new Secre-

tary of the Society, was present and brought some interesting news from the national headquarters. Committees were appointed to make arrangements for a convention.

The next meeting was held on June 6th, when the Entertainment Committee held a smoker and vaudeville entertainment for the members. The attendance was 55.

Generally the "last meeting" means "quiet until fall" but such is not the case with the Michigan Chapter. Committees are busy and every one is planning for the Semi-Annual Meeting on July 19-21, and it is hoped that all who come will not only see Detroit at its best, but also remember the Michigan Chapter.

WM. F. McDONALD, *Secretary.*

## NEW YORK CHAPTER

Monthly meetings of New York Chapter have been held from October until April with the exception of the month of January, the meeting for this month being merged with the Annual Meeting of the national Society, which occurred in the same week. An innovation in the meetings has been adopted, in making them more social than technical in character, only two technical meetings having been held during the year; those were the November and December meetings.

The November meeting was given over to a discussion of "Operating Costs of Heating Plants," discussed by Mr. Geo. W. Martin, member. The December meeting was devoted to "Vapor Vacuum Systems," the discussion being general.

The October, February, March and April meetings were social meetings, the Chapter in each instance paying for the entertainment of the Members attending. The October meeting was in the form of a Smoker at Keen's Chop House on 36th Street, and was addressed by Mr. Rawson W. Vail and Mr. R. D. Hopkins.

The February meeting was a get-together meeting and addresses were made by Dr. M. W. Franklin and Mr. F. K. Chew and others. At the March meeting, the principal speaker was Mr. Chas. E. Carpenter of the E. F. Houghton Co., while at the May meeting, Prof. Chas. E. Lucke, of Columbia University, favored the Chapter with a talk on "Modern High Speed Gas Engines," in which he showed in a very interesting manner, that this subject was one of interest to the heating engineer.

Beginning with the April meeting, the suggestion of Mr. Ritter was carried out that a portion of the membership of the Chapter be

put on a committee each month to handle the meeting and entertainment for that month, and to arrange the size and personnel of the committee in such a manner that at some time during the year each and every member would serve on a meeting committee. This has been eminently successful in the two meetings held since, Mr. P. H. Seward having charge of the April meeting and Mr. A. S. Armagnac having charge of the May meeting, which was the annual dinner of the Society.

The officers elected for the Chapter are as follows:

*President,* ARTHUR RITTER,
*Vice-President,* FRANK K. CHEW,
*Secretary,* F. K. DAVIS,
*Treasurer,* W. S. OLVANEY,

*Board of Governors,*
W. H. DRISCOLL,
CONWAY KIEWITZ,
C. E. PEARCE.

General interest in the Chapter has been greatly stimulated this year and the attendance has been increased to more than double of the average attendance one year ago.

The finances of the Chapter are in a healthy condition and a substantial surplus is held in the treasury. After expending considerable money in the entertainment of the members at the three social meetings of the year, and printing a Year Book, we will close the year with practically as much cash on hand as at the beginning of the year.

F. K. DAVIS, *Secretary.*

## OHIO CHAPTER.

The progress of the Ohio Chapter has not been phenomenal, due to the fact that the profession and business interests of our members have been so taken up as to make it almost impossible for them to give the attention to the Chapter affairs that they would have liked. Up to the present time the efforts have been extended toward an increase in membership, but still at the same time we have outlined a program of particular interest and importance to the heating and ventilating engineer. Papers now in progress give promise of exceptional value, not only to the Society and Ohio Chapter in particular, but to those interested in heating and ventilating in general. Among our many problems is a revision of the State Code, covering heating and ventilating apparatus for public buildings, and a committee has been appointed to prepare an extensive paper on this subject with the hopes of interesting the proper authorities and eventually encouraging legislation to cover some of the recommendations we propose to offer.

The inception of the Ohio Chapter was brought about by a desire of a few members of the Society to encourage the work of the parent body, particularly in the state of Ohio, and on the evening of January 11, 1916, a meeting was called for the purpose of considering the organization of Ohio Chapter, which was attended by the following members of the Society: Wm. M. Kingsbury; R. S. Mayer; M. L. Foote; F. H. Valentine; and F. G. Phegley.

A petition was signed at this meeting and forwarded to the general secretary at New York praying for a charter for the Chapter, which after due time was granted, and at this meeting it was arranged to call a second meeting and invite all members of the Society living in the State of Ohio. The second meeting, held on February 15, was more largely attended, and a committee was appointed to draft a constitution and by-laws to govern the Chapter. The third meeting of the temporary organization was held on the evening of February 28, 1916, at which time the proposed constitution and by-laws were adopted subject to the approval of the Council of the Society and the following officers elected:

*President,* R. S. MAYER,
*Vice-President,* M. L. CROWELL,
*Secretary,* F. G. PHEGLEY,
*Treasurer,* F. H. VALENTINE.

*Board of Governors,*

R. S. MAYER,
W. C. GREEN,
J. H. BACON, JR.,
F. G. PHEGLEY,
WM. M. KINGSBURY,
M. L. CROWELL,
F. H. VALENTINE.

The meeting of March 10, was devoted to the consideration of ways and means to increase the membership and a committee appointed to report at the next meeting a list of engineers who might be eligible for affiliation in our Society.

The meeting of April 14, 1916, was again taken up with the subject of new members, but it was impossible to show much progress as the committee appointed was not in a position to make a report.

The charter member list was closed at this meeting with the following membership considered as charter members of the Ohio Chapter:

| | |
|---|---|
| J. H. BACON, JR. | Cleveland |
| M. L. CROWELL | Cleveland |
| WM. C. M. CLARK | Cleveland |
| D. W. CHAPMAN | Canton |
| C. W. COLBY | Toledo |
| A. G. CRIPPS | Akron |
| M. L. FOOTE | Cleveland |
| W. C. GREEN | Cincinnati |
| M. J. GIBBONS, JR. | Dayton |
| H. C. HEWITT | Cleveland |
| THEO. F. HUMPHREYS | Cleveland |
| C. F. JORDAN | Cincinnati |
| WM. M. KINGSBURY | Cleveland |
| O. J. KUENHOLD | Cleveland |
| WALTER KLIE | Cleveland |
| ROBT. J. MAYER | Cleveland |
| R. S. MAYER | Cleveland |
| F. G. PHEGLEY | Cleveland |
| E. A. STARK | Cleveland |
| S. F. SMITH | Cleveland |
| O. H. SCHLEMMER | Warren |
| G. M. TAIT | Mansfield |
| F. H. VALENTINE | Cleveland |
| W. B. VAN SICKLE | Cleveland |
| ROBT. N. WAGENER | Canton |

At this meeting Mr. E. A. Stark presented a paper on "Chimney Sizes and Draft," which was interesting not only to the members present, but also to the visitors. It is interesting to note that a representative from the smoke prevention department of the City of Cleveland was present at this meeting.

The final meeting of the season was held on May 12, 1916, but the majority of members were out of town on business and there was nothing of importance considered.

The next regular meeting will be held in October and monthly meetings will be held on the second Friday of each month thereafter up to and including the month of May, 1917. There are many papers of interest and importance now being prepared and the present outlook is such as to warrant the statement that our membership will be more than double before we have the pleasure of presenting another annual report.

FRANK G. PHEGLEY, *Secretary*.

## EASTERN PENNSYLVANIA CHAPTER

The formation of the Eastern Pennsylvania Chapter was directly traceable to the fact that the members residing in the territory within its jurisdiction were last year given an opportunity to co-operate with the national Society at the Semi-Annual Meeting held in Atlantic City, in September, 1915.

The interest aroused at that time crystallized the idea with the members in this section, that a local Chapter would be advantageous, and on March 8, 1916, an organization meeting and banquet were held at Kugler's Restaurant, Philadelphia, at which thirty-six members were present. At that meeting, the following were elected officers of the Chapter:

*President,* JOHN D. CASSELL,
*Vice-President,* ISAAC H. FRANCIS,
*Secretary,* GEORGE W. BARR,
*Treasurer,* KENNEDY DUFF.

*Board of Governors,*
W. G. R. BRAEMER,
JAMES T. MELLON,
E. T. MURPHY.

A Committee on the Constitution and By-Laws, consisting of the officers and members of the Board of Governors, together with Mr. E. S. Berry and Mr. A. S. Mappett was appointed to report at the next regular meeting.

A suitable place for meetings was discussed in detail and in accordance with action taken at that meeting, application was made to the Engineer's Club of Philadelphia for associate membership. In due course, the members of our Chapter were elected associate members of the Engineer's Club of Philadelphia and the headquarters of the Chapter are now at 1317 Spruce Street, where the regular meetings of the Society are held on the second Thursday of each month from October to May, inclusive.

The first regular meeting was held at the Engineers' Club on April 13, 1916, at which the report of the Committee on the Constitution and By-Laws, appointed at the organization meeting, was submitted. This report was adopted with minor changes.

A very interesting paper on Air Conditioning was read by Mr. W. G. R. Braemer, a member, and was thoroughly enjoyed by the large number of members present. After a discussion of the paper, Mr. George Bliss, the Chief of the Philadelphia Weather Bureau, called attention to the importance of the reports of that Bureau in connection with the design of air conditioning apparatus.

The paper submitted at the second meeting of the Chapter on Thursday, May 11, was on Refrigeration, read by Mr. Lee Nus-

baum. This paper proved to be of particular interest to the members and resulted in a very interesting discussion on the subject of refrigeration in general.

At this meeting, the following special committees, by vote of the members, were appointed:

PUBLICITY: H. P. Gant, *Chairman,* A. C. Edgar, R. C. Morgan.

LEGISLATION: E. S. Berry, *Chairman,* A. J. Jellett, Lee Nusbaum.

MEMBERSHIP AND MEETINGS: George Boon, *Chairman,* A. P. Goldsmith, H. C. Beatty.

The Chapter is looking forward to the resumption of the meetings, which undoubtedly will develop a larger interest in engineering as applied to heating and ventilation, and the closer co-operation of the members to effect tangible and permanent results along ethical and legislative lines.

G. W. BARR, *Secretary.*

# PAPERS

OF THE

# SEMI-ANNUAL MEETING

JULY 19, 20 AND 21, 1916

# No. 415

# REPORT RELATIVE TO THE BEST POSITION FOR A RADIATOR IN A ROOM

YOUR Committee appointed to determine the best position for a radiator in a room, reports the following:

The tests reported herein were conducted in the Mechanical Laboratory of the University of Michigan by Professor J. E. Emswiler, in charge of the experimental laboratory. They were

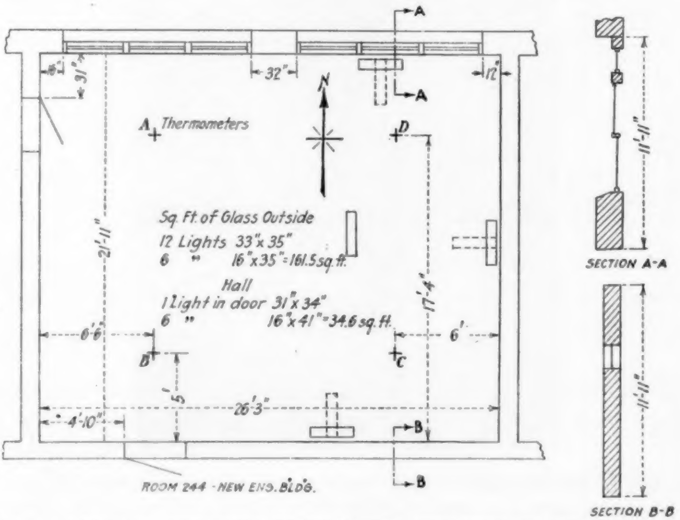


FIG. 1. ROOM IN THE NEW ENGINEERING BUILDING IN WHICH TESTS WERE CONDUCTED.

made in Room 244 of the New Engineering Building, which is a room 22 by 26 ft., with the west wall exposed. Fig. 1 gives the principal dimensions.

Presented at the Semi-Annual Meeting of THE AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Detroit, Mich., July, 1916.

A steel radiator was used which had welded joints, and 48 sq. ft. of rated surface. It consists of 12 sections, 8¼ in. in width by 33 in. in height, and was provided with rubber hose connections to the steam supply, also to the drain and by-pass. The steam upon passing through a valve on the steam supply line entered the rubber hose leading to the radiator. On the steam inlet side of the radiator

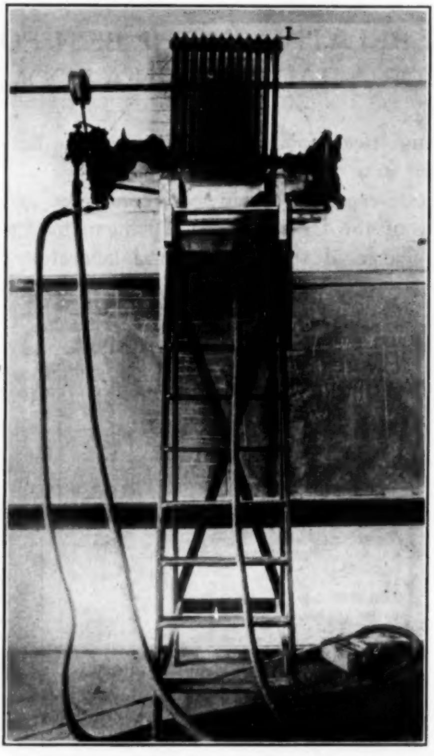

FIG. 2. ARRANGEMENT OF RADIATOR FOR TESTING IN ELEVATED POSITION.

were placed a separator with a by-pass, a valve for controlling the pressure, and also a pressure gage. There was also on the steam inlet side of the radiator, an orifice to insure a slight superheat and a thermometer for obtaining the temperature of the steam entering the radiators. A U-tube was placed near the top on the return side of the radiator for obtaining the pressure in the radiator.

The return connections consisted of a receiver provided with a glass tube for noting the level of the water in the receiver, which level was kept at the same point when securing results. A pet cock was placed on top of the receiver, through which a small amount of steam was allowed to flow at all times, thus keeping the radiator free of air. The condensation was taken off at the bottom of the receiver through a valve and rubber hose connection to a weighing scales and weighed. Readings were taken at ten minute intervals, the tests on the average lasting an hour. To be sure that the radiator was free from air, a thermometer was placed between the radia-

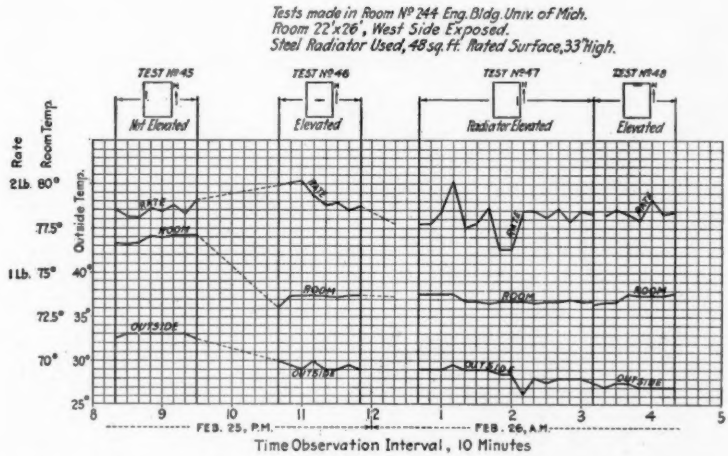


FIG. 3. CURVES SHOWING ROOM TEMPERATURES, OUTSIDE TEMPERATURES AND WEIGHTS OF CONDENSED STEAM PER 10 MIN. FOR RADIATOR IN DIFFERENT POSITIONS AND LOCATIONS IN ROOM.

tor and the receiver, thus giving a temperature check on the steam in the return. Fig. 2 shows the radiator in an elevated position preparatory to a test.

Twenty-two sets of tests were made between February 12th and 26th, 1916, with the radiator in ten different locations, seven on the floor and three elevated. Table 1 gives results obtained from these tests. Table 2 is obtained by averaging the results given in Table 1 for the ten different locations. Curves were plotted showing room temperature average, outside temperature and weight of condensed steam at ten minute intervals. The results obtained are quite consistent. They cover not an unusual range in values as will be noted from the following, taken from results as shown in Table 1:

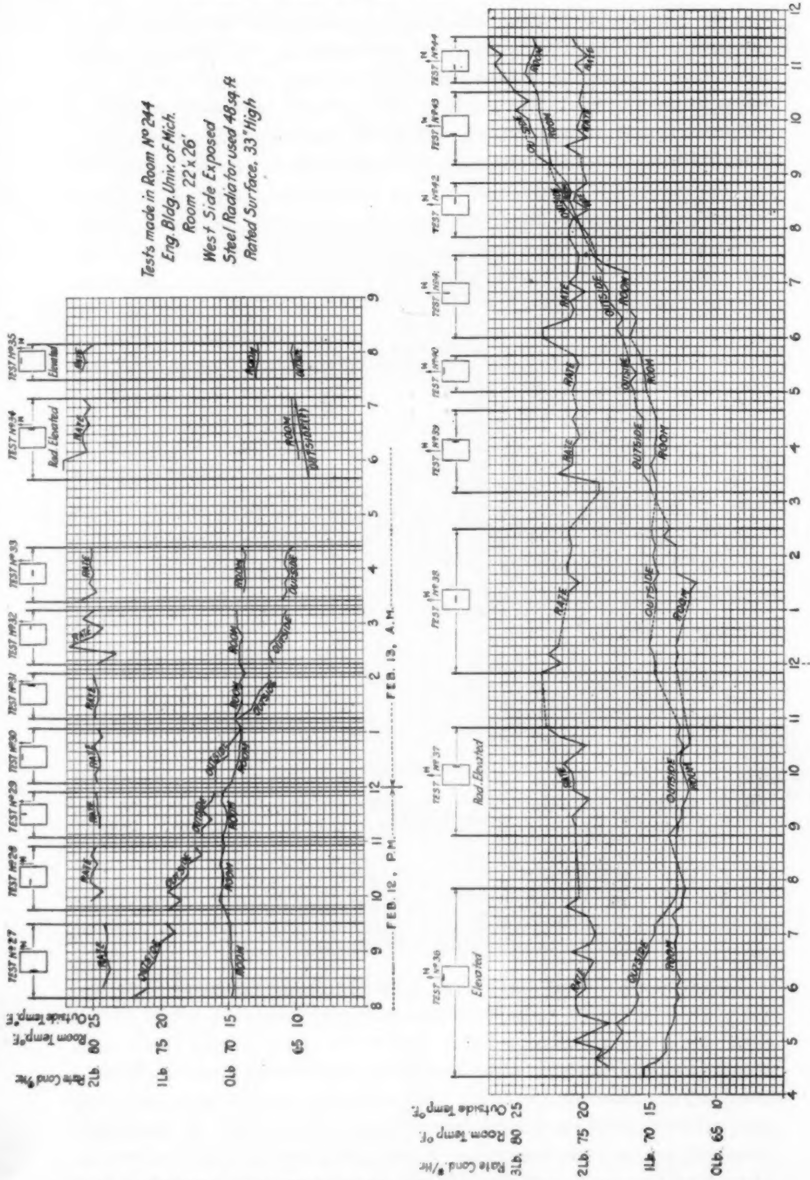


FIG. 4. CURVES SHOWING ROOM TEMPERATURES, OUTSIDE TEMPERATURES AND WEIGHTS OF CONDENSED STEAM PER 10 MIN. FOR RADIATOR IN DIFFERENT POSITIONS AND LOCATIONS IN ROOM (cont.).

TABLE 1. RESULTS OF THE 22 TESTS MADE WITH THE RADIATOR IN 10 DIFFERENT POSITIONS.

| Test No. | Location of Radiator | | | Average Temperatures | | | | | | Max. Temp. Range | Lb. Steam per 10 min. | B.T.U. per Hour | Value of "K" |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Wall | Floor or Ceiling | Perpendicular or Parallel | Out-side | In-side | A | B | C | D | | | | |
| 27 | West | Floor | Par. | 20.4 | 69.8 | 68.7 | 69.6 | 70.3 | 70.8 | 2.1 | 1.815 | 10553 | 1.525 |
| 28 | West | Floor | Perp. | 18.3 | 70.5 | 69.4 | 70.3 | 71.1 | 71.4 | 2.0 | 1.990 | 11565 | 1.670 |
| 29 | North | Floor | Perp. | 16.6 | 70.4 | 69.1 | 70.0 | 72.0 | 70.7 | 2.9 | 1.942 | 11284 | 1.630 |
| 30 | North | Floor | Par. | 15.2 | 69.4 | 68.0 | 69.3 | 70.4 | 70.0 | 2.4 | 1.941 | 11284 | 1.620 |
| 31 | East | Floor | Par. | 12.9 | 69.2 | 67.6 | 69.7 | 70.7 | 69.0 | 3.1 | 1.968 | 11439 | 1.640 |
| 32 | East | Floor | Perp. | 11.4 | 69.3 | 67.7 | 69.7 | 70.9 | 68.8 | 3.2 | 2.000 | 11623 | 1.665 |
| 33 | Center | Floor | East & West | 10.6 | 69.0 | 67.7 | 69.1 | 69.7 | 69.4 | 2.0 | 2.034 | 11817 | 1.690 |
| 34 | East | Ceiling | Par. | 10.0 | 65.5 | 64.3 | 65.9 | 66.9 | 64.8 | 2.6 | 2.110 | 12262 | 1.710 |
| 35 | North | Ceiling | Par. | 10.5 | 64.0 | 64.0 | 65.6 | 64.4 | 66.2 | 2.2 | 2.105 | 12230 | 1.700 |
| 36 | North | Ceiling | Par. | 15.0 | 67.4 | 68.4 | 67.0 | 67.8 | 66.4 | 2.0 | 1.988 | 11550 | 1.633 |
| 37 | East | Ceiling | Par. | 13.1 | 67.7 | 66.5 | 67.8 | 69.3 | 67.1 | 2.8 | 2.087 | 12128 | 1.720 |
| 38 | Center | Floor | East & West | 13.1 | 69.7 | 68.6 | 70.1 | 70.8 | 69.3 | 2.2 | 2.184 | 12694 | 1.829 |
| 39 | East | Floor | Par. | 15.5 | 69.7 | 68.2 | 70.1 | 71.1 | 69.2 | 2.9 | 2.115 | 12269 | 1.730 |
| 40 | North | Floor | Par. | 16.4 | 70.5 | 68.9 | 70.6 | 71.9 | 70.7 | 3.0 | 2.116 | 12286 | 1.759 |
| 41 | North | Floor | Perp. | 18.0 | 71.4 | 70.6 | 72.3 | 72.4 | 72.4 | 1.8 | 2.105 | 12220 | 1.756 |
| 42 | East | Floor | Perp. | 20.8 | 75.6 | 74.8 | 75.1 | 76.9 | 75.7 | 2.1 | 2.082 | 12064 | 1.753 |
| 43 | West | Floor | Par. | 23.9 | 78.0 | 77.1 | 77.8 | 78.4 | 78.7 | 1.6 | 2.056 | 11898 | 1.730 |
| 44 | West | Floor | Perp. | 26.3 | 79.0 | 77.7 | 78.8 | 79.2 | 80.1 | 2.4 | 2.060 | 11935 | 1.770 |
| 45 | West | Floor | Par. | 32.8 | 77.1 | 75.5 | 76.5 | 76.9 | 78.9 | 3.4 | 1.704 | 9943 | 1.510 |
| 46 | Center | Ceiling | East & West | 29.4 | 73.8 | 72.6 | 73.7 | 75.0 | 73.8 | 2.4 | 1.750 | 10177 | 1.510 |
| 47 | East | Ceiling | Par. | 26.7 | 73.5 | 72.4 | 73.7 | 75.0 | 73.0 | 2.6 | 1.667 | 9695 | 1.440 |
| 48 | North | Ceiling | Par. | 27.2 | 73.8 | 72.6 | 74.0 | 74.6 | 73.8 | 2.0 | 1 684 | 9794 | 1.460 |

TABLE 2. AVERAGES OF THE RESULTS OF TESTS WITH THE RADIATOR IN THE 10 DIFFERENT POSITIONS.

| Test No. | Location of Radiator | | | Average Temperatures | | | | | | Max. Temp. Range | Lb. Steam per 10 min. | B.T.U. per Hour | Value of "K" | B.T.U. per Hour per deg. diff. Air |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Wall | Floor or Ceiling | Perpendicular or Parallel | Out-side | In-side | A | B | C | D | | | | | |
| 27 43 45 | West | Floor | Par. | 25.7 | 75.0 | 73.8 | 74.6 | 75.2 | 76.1 | 2.3 | 1.858 | 10798 | 1.588 | 219 |
| 28 44 | West | Floor | Perp. | 22.3 | 74.5 | 73.6 | 74.6 | 75.2 | 75.8 | 2.2 | 2.025 | 11750 | 1.720 | 224 |
| 29 41 | North | Floor | Perp. | 17.3 | 70.9 | 69.8 | 71.2 | 72.2 | 71.6 | 2.4 | 2.024 | 11752 | 1.693 | 219 |
| 30 40 | North | Floor | Par. | 15.8 | 70.0 | 68.5 | 70.0 | 71.2 | 70.4 | 2.7 | 2.028 | 11785 | 1.700 | 217 |
| 35 36 48 | North | Ceiling | Par. | 17.6 | 68.3 | 68.3 | 68.9 | 68.9 | 68.8 | 0.6 | 1.926 | 11191 | 1.598 | 220 |
| 31 39 | East | Floor | Par. | 14.2 | 69.4 | 67.9 | 69.9 | 70.9 | 69.1 | 3.0 | 2.042 | 11854 | 1.685 | 215 |
| 32 42 | East | Floor | Perp. | 16.1 | 72.4 | 71.2 | 72.4 | 73.9 | 72.2 | 2.7 | 2.041 | 11844 | 1.709 | 210 |
| 34 37 47 | East | Ceiling | Par. | 16.6 | 68.9 | 67.7 | 69.1 | 70.4 | 68.3 | 2.7 | 1.955 | 11362 | 1.623 | 217 |
| 33 38 | Center | Floor | East & West | 11.8 | 69.4 | 68.2 | 69.6 | 70.2 | 69.4 | 2.0 | 2.109 | 12256 | 1.760 | 213 |
| 46 | Center | Ceiling | East & West | 29.4 | 73.8 | 72.6 | 73.7 | 75.0 | 73.8 | 2.4 | 1.750 | 10177 | 1.510 | 229 |

| | | | |
|---|---|---|---|
| Outside Temperature, deg. | 10.0 | to | 32.8 |
| Inside Temperature, deg. | 64.0 | to | 79.0 |
| Maximum Temperature Range in Room, deg. | 1.6 | to | 3.4 |
| Value of $K$ (B.t.u. per sq. ft. per hour per degree of difference) | 1.44 | to | 1.829 |

In averaging the results for the ten different positions the range is not so marked:

| | | | |
|---|---|---|---|
| Outside Temperature, deg. | 11.8 | to | 29.4 |
| Inside Temperature, deg. | 68.3 | to | 75.0 |
| Maximum Temperature Range in Room, deg. | 0.6 | to | 3.0 |
| Value of $K$ | 1.510 | to | 1.760 |
| B.t.u. per hour per degree of difference inside and outside air | 210 | to | 229 |

The greatest value of $K$, 1.760, is obtained when the radiator is placed in the center of the room (see Table 2). This indicates that more B.t.u. are secured per sq. ft. per degree difference between the steam in the radiator and the average temperatrue of the room, in this position than in any other. The temperature range indicated by the four thermometers, 2.0 deg., is next to the smallest and it will be noted that the B.t.u. given up by the radiator, 213 B.t.u. per degree difference, is below the average. This last, however, may be due to other causes, such as varying wind conditions outside.

With the radiator placed in the usual position, parallel to the wall and under the exposed glass surface, the value of $K$ is 1.588, the maximum temperature range in the room is 2.3 deg. and the B.t.u. per degree difference given up by the radiator is 219 B.t.u. 1.51 is the lowest value of $K$, which was obtained with the radiator elevated in the center of the room. The corresponding value of the B.t.u. per hour per degree difference of outside air and inside air is 229, which is a maximum for the ten different positions.

W. F. Verner,
J. R. Allen,
R. Collamore,
*Committee.*

## DISCUSSION

A. S. ARMAGNAC: This report supplements one made by Mr. F. K. Davis, of New York, to the Society some years ago. Mr. Davis reported the results obtained by placing radiators in different positions in the room and he came to the same conclusion as that here given, that a radiator placed on the inside wall, or at least away from the window, is more efficient, as far as the heating of the room is concerned, than one placed directly under the window. As I remember his theory, it was that a radiator placed close to an outside window induces a current of cold air from the window and while the radiator actually does more heating work under those conditions, it does so at the expense of the room; that is to say, a greater amount of outside air is drawn into the room.

JOHN F. HALE: Something similar to this was brought to my attention a few days ago. Samuel R. Lewis, one of our Ex-Presidents, designed a heating apparatus for a small residence in a brick row, an old building which was being remodeled; it was in a district where fine residences were not continued, but it was owned by a doctor who was compelled to keep his residence in that neighborhood because his patients were nearby. Mr. Lewis first designed a heating apparatus with all of the radiators on the inside wall, that is, in the center of the building; primarily because the lady of the house insisted that the positions where all her furniture were located at that present time, must not be changed; and it was necessary to find some place to put the radiators, and the only place was on the inside wall. So Mr. Lewis designed the apparatus on that basis, and he told me the other day he felt confident, from the experiments he had made, that there would be no question at all but that it would heat, because he had compensated for what little difference there may be due to the location. He put all the radiators in the center with the building, with only two or three small risers, instead of distributing them all around the outside walls. The risers run straight up, within a few feet of a vertical line, above the point where the boiler would be located.

WM. J. BALDWIN: Some of these ideas are rather radical, and probably it would be well to consider a little what they mean. If a radiator is placed on the inside wall of a room, the air, of course, reaches the ceiling first, then passes across the ceiling to the window (the cold place), and there falls down, and flows across the floor to the radiator again. A man sitting in this return current of air, or a woman, with poor circulation, will complain of cold feet.

I think I made use of the "cold feet" idea once before, and I was laughed at, but I will have the courage to use it again. *Cold feet* makes the condition plain to nearly all of us.

A radiator placed under a (cold) window is the neutralizer of the cooling surface above it; and I think that is the only way to make a room comfortable at the least cost and with the least effort. An ordinary room is a cube, or cubiculum—I am not considering a corner room, which has two windows in it, but a second room. Now, the only cooling going on in that room is done at its window and the outside wall. If you neutralize this cooling by heat just inside the window, you do that at a minimum of cost and of condensation; and tests will show less condensation in a radiator so placed. The assumption that the radiator is doing more work on the inside wall, does not prove that the room will be more comfortable, and it does prove, if anything, that it will require more steam and probably a larger radiator.

I am putting it in this way, dogmatically, to fix questions in my mind, and in the minds of many of us. I might explain. Prof. Louis Leeds in a work on ventilation, in the early sixties, illustrates this subject with colored diagrams. He says that when the fireplace is on the inside, or the heat on the inside wall, that a person to have comfort should be turned upside down, their feet should be near the ceiling, and their heads at the floor, and he shows a chair, and an old lady sitting in it, her head near the floor and her feet in the warm air. Now, that is the condition in a room, if you put the radiator on the inside wall and neglect the windows. The warmer air is flowing across the ceiling, towards the glass. The window is "the negative circulator"; that moves the air downwards; the *prime* circulator is the radiator that moves the air upwards. I am reasoning to show what happens to this air, if we put the radiator in the inside wall and do nothing for the windows. If we put the radiator on the outside wall, the flow is more or less the other way, and not so very much the other way, either, because the heat of the radiator meets the air flowing down from the glass or trying to fall down, and the hot meets the cold and warms it, and we get a rolling circulation, between the current of warm air going up, and the current of cold air coming down. That is the way I think we should look at it, as a suggestion to at least the younger members.

JAMES A. DONNELLY: One of the sources of discussion on this Report might be found in just one word in the title which reads as follows: "Relative to the Best Position for a Radiator in a Room."

I have not the slightest idea of what is meant by the word—"Best." Is it the best position of the radiator in relation to the amount of steam used? In relation to the size of the radiator necessary? In relation to the heat given off by the radiator? In relation to the uniformity of temperature in the room, in the vertical zone, the horizontal zone? Or in relation to the comfortable heating of the room?

My own inclination is to use the word "best" in relation to the comfortable heating of the room; in relation to the uniformity of temperature in both vertical and horizontal zones; in relation to what the man wishes who is using the room. A comfortable room to sit in, to read in and to have children playing about the floor, as Mr. Baldwin says, needs the best location for the radiator, but until there is a definition of what is meant by "best," we each may discuss this paper from an entirely different aspect and we might all disagree. While it is best not to be too technical in the use of words, yet a little more care in defining them will bring out a discussion from the same point of view, from which we are all talking.

WM. J. BALDWIN: In mills, commencing twenty or thirty years ago, it became quite the practice to put the coils along on the outer side, above the windows, and near the ceiling, and it was considered the best practice in the mills at that time. The Massachusetts Mutual Society for insuring mills approved of it. Why they approved of it was, that in their judgment it was the "best" place to put heaters, because it minimized the chances of fire in the mill. But, an operative working under the coil often had a headache, while complaining of cold feet; so then it became necessary to place hanging shields beneath the coils, to cut off the radiant heat that caused the headache. Radiators, of course, give off heat by two methods, convection and radiation, and the radiation question is an important one, when considering location of coils or heaters for factories.

In the Winchester Repeating Arms Company building, the men work near the windows. The windows are large, get a good deal of light and the question as to whether the coils were to be placed at the ceiling or behind the benches, came up for consideration. One said: "Place them behind the benches, of course"; another said: "The warmer air comes out from under the benches, and comes into one's face." A little discussion of the matter brought the suggestion: "Why not move the benches out a little and let the air come up behind the benches?" So the benches were moved

6 in. or so from the walls and the circulation now goes up in front of the glass, in the usual old-fashioned way and the movement of air is now from the body of the workman underneath the bench, and up the outside wall, neutralizing the cold of the wall and the windows. In that particular case, that was "the best" way in that mill, the overhead method being "the best" for cotton mills.

I believe it will be found that there is economy also in using the heating surfaces close to the cooling surfaces—the walls and windows. If we put the heaters on the inner walls there will have to be more of them to do the same work and if we put them on the outer walls, we are simply neutralizing the cold where we want it and we can do it with less radiator than when the radiator is on the back wall and do it more satisfactorily.

H. M. HART: I think the point is well taken, that we must distinguish between the efficiency of the radiator, and comfort in the room. There is no question in anybody's mind but that as far as the question of efficiency is concerned, this report gives us the most efficient place, or point, to locate the radiator in the room. As far as the steam consumption is concerned, we all know that if we place the radiator against the outside wall, that the radiant heat on the outside of that radiator is practically lost, because it is up against the great cold surface and goes out through the window, or out through cold wall, and is heating out-doors. The point that Mr. Lewis made was that he wanted to save that radiant heat that is now escaping out-doors, by placing the radiator on the inside wall. There is no question but what that point is well taken, but we have got to consider the comfort of the occupant, the cold draught on the floor, which is liable to result, and I think it might be well to compromise by placing the radiator on an inside partition near the outside wall which would probably prevent the cold draught passing clear across the floor from one side of the room to the other.

JOHN F. HALE: One thing we can learn from this paper, if it is to be carried to a further development, is, to give the engineer the result of the experiments, so that if he meets a problem where furniture location prevents radiators being located near the windows, he can find a way of putting them at some other point. If it indicates to what extent to increase the radiation to overcome that difficulty, the paper has accomplished something; it has given the engineer something to work upon.

I do not believe it was the thought to determine whether it was better in every case, regardless of furniture location, to put the radiator against the wall on the inside than against the outside wall, but rather to give the engineer some results of the experiment and also to show that if he was thrown up against that problem, he would know how to meet it.

H. M. HART: If there is no further discussion on this report, some action should be taken as to whether we should accept it, or refer it back to the Committee for further information. I think the report is worthy of acceptance, because it seems to be quite complete, and gives us some data that is interesting.

J. D. CASSELL: Owing to the matter brought out by Mr. Donnelly, I move that the report be received and the Committee continued for further experimentation and report.

(The motion was seconded and carried.)

No. 416

# DESIGN AND OPERATION OF FRACTIONAL VALVES

By James A. Donnelly, New York

**Member**

FRACTIONAL valves for the control of the partial heating of steam radiators have been in use for many years. It is, however, only recently that they have come into wide use in this country, although they are almost universally used in Europe. Fig. 1 shows one of the earliest types of fractional valves made in this country. It was manufactured by Frederick Tudor about forty years ago.

Modern types of valves are used under very diversified conditions, but the tendency of the best and most conservative practice of this country, at the present time, seems to be toward the larger sizes of American practice, rather than the smaller sizes of European practice. It was thought, therefore, that in this investigation of the subject, the research work should be directed toward the testing of fractional valves and the determination of the necessary orifices through them, where they were designed to be used under the conditions fixed by the standards that have been suggested to the Society, as representing the best of present practice for low pressure plants. These may be briefly stated as follows:

*a.* That the valve is to be adapted for use on, and rated for standard cast iron direct radiation, having a nominal condensing capacity of 0.25 lb. of steam per square foot per hour;

*b.* That the steam and return mains are of such size that the drop in pressure is not greater than one ounce in 100 ft. in straight pipe;

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*c*. That the standard sizes of steam and return connections for two-pipe vapor and vacuum systems are to be used, which are substantially as follows:

| | SUPPLY | | RETURN | |
|---|---|---|---|---|
| Size in. | Gravity and vacuum steam connection | Gravity and vacuum valve | Gravity return | Vacuum return |
| ½ | ... | 20 | 40 | 80 |
| ¾ | 20 | 40 | 100 | 200 |
| 1 | 40 | 80 | 200 | 400 |
| 1¼ | 80 | 160 | ... | ... |

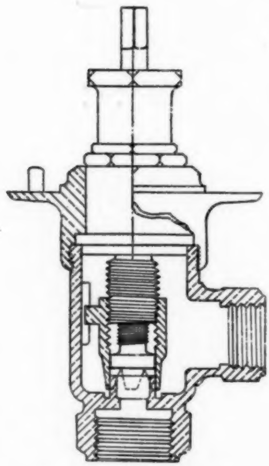

FIG. 1. AN EARLY TYPE OF FRACTIONAL VALVE.

Fractional valves are in general use in two broad classes of air return systems: *First*, gravity systems, which include those in which the water is returned by gravity to the boiler, tank trap, return trap, receiver or other device, and *second*, vacuum return line systems, in which a vacuum pump is used on the return line in order to establish and maintain the difference in pressure necessary for circulation by lowering the pressure in the return line.

The gravity systems may be divided into three classes along the lines of the devices used on the outlet of the radiator. The *first* class is that which uses nothing more than a union elbow, a slight water seal or a check valve of unrestricted opening; the *second* class is that which uses a check valve having a seat opening restricted in size or by the weight of the valve disc, or both; the *third* class is

that which uses a float valve, thermostatic or vaporizing fluid device on the outlet.

The *first* class has substantially no restriction to the flow through the outlet device on the radiator; the *second* class modifies or reduces the flow to a greater or less extent; while the *third* class permits the escape of air and water from the radiator and prevents the flow of any steam. The function of the fractional valve is, therefore, somewhat different in each class.

In the *first* class, the maximum opening through the valve is limited to such a size that, at the pressure used, it will pass exactly the proper amount of steam for heating the radiator when the room is 70 deg. This valve, therefore, attempts to take the place of the outlet valve or to combine the function of both the outlet and the inlet valve, in one valve.

Fractional valves in the two remaining classes are usually made with a maximum opening, which is of sufficient size, at the pressure used, to heat the radiators in a reasonable time, and depend upon the outlet valves to prevent the passage of steam or reduce the flow to a proper amount.

The vacuum return line systems may be divided into two classes: *First,* simplex systems, or those which use but one device and that at the outlet of the radiator, for controlling the circulation and *second,* compound systems which use a combination of two devices for controlling the circulation, one at the outlet of the radiator and the other in the branch return.

In the *simplex* systems, the full vacuum produced by the vacuum pump, less the unavoidable friction, extends to the return devices on the outlet of the radiator, and therefore, as soon as the heating effect of the radiator is reduced below the maximum, by the action of the fractional valve, the outlet valve tends to cool, and if of thermostatic or vaporizing fluid design, it opens, reducing the pressure in the radiator to substantially that in the return pipe. If a float valve is used at the outlet, it will not open as a thermostatic valve does, and therefore the pressure in the radiator will be reduced only by the continued throttling action of the inlet valve, until equal to that in the return piping. This, by reason of the increased difference in pressure, renders it necessary that the fractional valve for these systems shall have a very much smaller area of opening through the seat, in order to control the flow of steam.

In the *compound* system, the full vacuum maintained by the pump is not allowed to extend to the outlet device on the radiator, but is reduced to that necessary for circulation in each group. Fractional valves for these systems will, therefore, be working under

substantially the same conditions as those found in the second and third classes of the gravity systems.

The necessary orifice through the seat of the fractional valves will, of course, be entirely governed by the drop in pressure chosen as a standard from the steam connection through the valve to the radiator. Fractional valves vary in their individual design so much at the present time that it was thought advisable to prepare a chart of pressures and areas showing a considerable range. Therefore, the chart shown in Fig. 2 was prepared, showing the area of orifices necessary, with differences in pressure from ½ oz. to 4 oz.

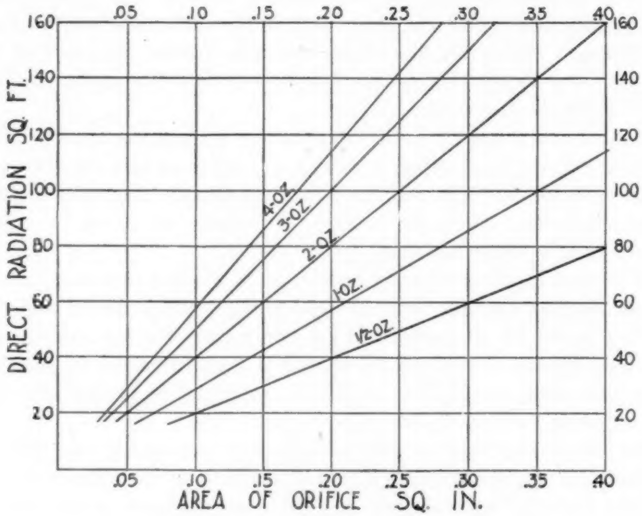


FIG. 2. CHART SHOWING AREAS OF ORIFICE NECESSARY WITH DIFFERENT PRESSURE DROPS.

The theoretical flow of steam may easily be figured as a check on this chart. Taking as an illustration the orifice necessary to heat a 40 sq. ft. direct radiator with 2 oz. drop to the sq. in., the calculations are as follows:

2 ounces per sq. in. = 18 lb. per sq. ft.

18 x 26.36 (cu. ft. in a pound of steam at atmospheric pressure) = 474.48, the head in feet.

$\sqrt{2gh} = \sqrt{474.48 \times 8.02} = 174.7$, the velocity in ft. per sec.

174.7 x 3600 = 628,920 ft. per hr.

40 sq. ft. of radiation x 0.25 = 10 lb. per hr.

10 x 26.36 = 263.6 cu. ft.

263.6 divided by velocity, $\dfrac{263.6}{628{,}920}$ = the area of the orifice in sq. ft. which multiplied by 144, equals 0.06 sq. in.

From the tests upon which the chart is based, it took 0.1 sq. in. in area to heat the radiator. This would give an efficiency of orifice of 60 per cent., which is very reasonable to expect in the circumstances.

If the size of pipe supplying the valve in which the orifice is located is sufficiently large so that the friction of flow through it does not materially affect the flow through the orifice, the area of orifice for varying amounts of radiation will vary in direct propor-


FIG. 3. SUGGESTED DIAL ARRANGEMENT FOR FRACTIONAL VALVES.

tion to the amount of radiation. As the difference in pressure for which the valve is designed varies, the area of the orifice will vary in inverse proportion to the square root of the difference in pressure.

In order that a fractional valve may have a sufficiently large opening to heat a radiator within a reasonable time, the maximum opening should be double that required for the normal heating of the largest radiator for which the valve is rated. If this is the case, the average radiator for which the valve is designed will be completely heated in from 10 to 15 min. after steam is turned on. This, in view of the comparative performance of ordinary direct radiators, is thought to be as rapid as necessary. If we assume a 2 oz. drop from the piping to the radiator, the maximum orifice for each size of fractional valve for the surface for which it is rated is as follows:

| | Square feet | Normal Heating | Initial Heating |
|---|---|---|---|
| ½ inch | 0 to 20 | 0.0 to 0.05 | 0.1 |
| ¾ inch | 21 to 40 | 0.05 to 0.1 | 0.2 |
| 1 inch | 41 to 80 | 0.1 to 0.2 | 0.4 |
| 1¼ inch | 81 to 160 | 0.2 to 0.4 | 0.8 |

The dial might, therefore, be arranged as shown in Fig. 3. At the point *A*, the valve would be shut, at *B* it would be open sufficiently for the normal heating of the smallest radiator for which the valve is rated, at *C*, for the normal heating of the largest radiator, and between the points *C* and *D* for the quick heating of a radiator. Between the points *A* and *B*, it would fractionally control the smaller radiator and between the points *A* and *C* the larger radiator.

If the resistances of valves and special devices are stated by the manufacturers, the total resistance of a circuit may easily be obtained and the static head of a gravity system, for instance, may easily be calculated and provided for.

As an illustration, consider a gravity air return system having a run of 100 ft.; the resistances will be as follows:

| | Oz. |
|---|---|
| Resistance of fractional valve .......................... | 2 |
| Resistance of outlet valve .............................. | 1½ |
| Resistance of steam main, including fittings, etc............ | 2 |
| Resistance of return main.............................. | 2 |
| | 7½ |

For such a plant as this, the lowest point in the dry return should be about 18 in. above the water line of the boiler, giving a static head of 10 2-3 oz.

## DISCUSSION

JOHN F. HALE: I notice the first paragraph of the paper speaks of Frederick Tudor having been the originator of this type of valve some forty years ago, which is my understanding also. It is my belief that Mr. Tudor's original idea was to produce a control valve, a valve that would control the quantity of steam to be conducted into a radiator of a given size, and for this reason, if the other valves which have been developed since that time, forty years ago, have all followed in Frederick Tudor's wake, they would attempt to get some such adjustment as is shown on page 457 of the paper, in order that the valve itself would control the unit of radiation to which it was attached.

On page 458, in the first paragraph, the commercial sizes of pipe which are purchasable, are shown as ½ in., ¾ in., 1 in., and 1¼ in. and it is further indicated that a ½ in. valve will supply up to 20 sq. ft. of radiation; that a ¾ in. valve will supply from 21 to 40 sq. ft., and so on. This in my estimation shows that the valve must be adjusted to its unit in order to take care of the control at the points between the commercial sizes. If a ½ in. valve will take care of 20 sq. ft. and will also take care of 10 sq. ft., or if a ¾ in. valve will take care of 22 and also 40 sq. ft., and is used only as a commercial opening size, it will not give the same control for a 40 sq. ft. radiator that it will for a 22 sq. ft., unless some means are provided whereby that valve can be made to fit the unit to which it is attached.

Some investigations which I have made have shown that this is quite desirable, and although Mr. Donnelly does not lay particular stress upon this, he touches upon it, showing that such control is desirable.

WILLIAM J. BALDWIN: I used the Tudor valve in my practice just after Mr. Tudor invented it. Mr. Tudor (supplementing what Mr. Hale said) had a "limiting device," in the form of a washer in the lower part of the valve, the inlet, with a hole bored through the washer, that was just the capacity to admit steam, say at two pounds pressure, to warm the radiator, and no more. Mr. Tudor used no valve on his outlet pipe; he used a deep loop, a water loop, and he used very large radiators. Where we might call for 100 sq. ft. of surface, Mr. Tudor would use 125 sq. ft. so as to prevent what we might call "an over-flow." The steam that passed through the punctured washer was sufficient only to warm a 125 sq. ft. radiator, to the extent of 100 sq. ft., doing an ordinary amount of work and no more.

That washer and its hole was really Mr. Tudor's patent. Mr. Tudor put this system in the Capitol at Albany and in two or three New York buildings and elsewhere, and I certainly consider him the pioneer in fractional-valve systems in this country, except maybe Birdsall Holly who used perhaps what is called a needle-valve before Mr. Tudor's time. The needle-valve was a long taper plug through a hole in a disc and Mr. Holly used a radiator open to the atmosphere. It was made of sheet iron or tin and every tube (every element or column of which) had a hole, or at least the last tube had a hole, near the bottom. The steam went in at the top of the loops and dropped down, expelling the air at the bottom hole. I refer to that as being a fractional atmospheric

system before Mr. Tudor's time, but Mr. Tudor was the first man in America, and probably in the world, that made the fractional system practical.

The Tudor valves would unfortunately become inoperative in a year or two for the reason that he used a thread on the stem of the valve as small as forty to the inch, and three-quarters of a revolution on this thread was all the lift (or the fall) of that very fine thread, that was available. It cut itself out.

There is in New York to-day at 40-42 Wall Street (the Manhattan & Merchants' Bank Building) a building designed to use Tudor valves, but for some reason Mr. Tudor would not sell his valves for the work. Johnson & Morris of New York were the contractors. They had to finish the work under their contract and they made a valve from the engineer's drawing. It was "the Hawley idea" of the long taper plug running through a long taper hole, the hole forming the seat of the valve. The long taper plug was operated by a thread of four to the inch, so that for an entire revolution of the handle there was a lift of ¼ in., increasing the annulus around the long taper plug, until the amount of steam necessary to fill the radiator was passed and regulated by the friction in the annulus.

In carrying out that work, not having Mr. Tudor's washers nor valves, the question arose: "How are we going to regulate for variations from 25 sq. ft. of surface to 150 sq. ft. of surface?"—the range of the sizes of the heaters. Well, it was done in what I will call the "seat"; the part of the valve in which this long taper plug passed, ran down to a very small hole, say one-sixteenth of an inch in diameter or no hole, and only one size of valve was used for every radiator. The valve was first calculated approximately, and by experiment, the size hole was found that would pass steam just sufficient for 25 sq. ft., 50 sq. ft., 75 sq. ft., 100 sq. ft., 125 sq. ft., and so on up. A nut was then made that would screw into every valve alike, when the center was taken out, and in that nut, Morse-drill size holes of various sizes were determined so that the particular Morse drill for the particular radiating surface was run through the bottom of the taper seat, thus making the limiting hole of the device. That work was done in 1883; and it is in operation to-day, with the long plug valve. I refer to this building because it is in operation on what may be called the Tudor system and it has survived service since 1883.

JOHN F. HALE: Speaking of the discs, or methods of changing the orifice, brings to mind the fact that there is a commercial valve

on the market to-day which is calculated to accomplish that same result and is provided with various sized discs. Last year I was out at the University of Nebraska where I visited Professor Hoffman and had a chance to talk with the class in engineering and, fortunately, there was a young man there from this other company that handles the valve with the discs. After the talk before the students, we had an opportunity to have a little conversation and he admitted that their greatest trouble was in the fact that steamfitters in the first place would not put the discs in correctly; in the second place, it was difficult to get them to put them in at all; and in the third place, if they did put them in, they found invariably that where they had trouble, the people would disconnect the union, pull the disc out and throw it away, put the valve back again and then it was nothing more or less than an opening and was not a control valve at all.

The last speaker mentioned the fact that sufficient surface was put into the radiators by Mr. Tudor to provide against the flow of steam into the return and that he would put in a 125 sq. ft. radiator where 100 sq. ft. were sufficient. While that happened forty years ago, it is strange to say that it is the practice to-day by some of the companies who want 25 per cent. more radiation put in the radiators in order to overcome that very same difficulty, due to the fact that their equipment on both ends of the radiator is not correct.

WILLIAM J. BALDWIN: The advantage that this particular valve, I described, had was that it anticipated the trouble with the fitting not being dependable. In this case one man with his assortment of drills went through the building and fixed the limiting hole. The drill for 25 sq. ft. was marked 25 and all that the workman had to do was screw the guide nut into the body of the valve and run the drill for the 25 or 40 radiator through the valve, as the case might be, and pass on to the next radiator.

H. M. HART: I wrote to the headquarters of the Society a couple of years ago and asked if anything had ever been presented to this Society that would give the proper size orifice for the so-called modulation systems; "what was the limit in the size of the radiator that could be fed through a certain size orifice?" The reply was that nothing along that line had ever been presented to the Society. I have been looking since then to find some actual test data and I have not been able to find anything that is very reliable.

Now, there is either one of two things happening: either the manufacturers of these valves are doing a lot of guessing, or else

they think they have got something that is a secret and do not want to give it out. I do not believe that the same rule would apply to all types of fractional valves due to the design of the orifice through which the steam is admitted, and due, as Mr. Donnelly has said, to the design of the return valve.

I connected up a 60 sq. ft. radiator in a temperature of 40 deg. (in fact it was outdoors) and ran a 2 in. pipe to a receiving tank, or expansion tank, with a sensitive pressure regulator on it adjusted so as to carry 8 oz. pressure at the inlet of the radiator, a glass tube being used for indicating the pressure that we had on the supply. The return was left open. We started with a flanged union, with a copper disc, by drilling a small hole through it and taking records of how long it took to fill that radiator with steam. I started with a hole 1/32 in. in diameter and the results were hardly perceptible in the radiator. But working from that up to an orifice, a round hole in this copper disc ¼ in. in diameter filled the 60 sq. ft. radiator with steam in this temperature of approximately 40 deg. in 30 minutes—that is my recollection.

On that basis I determined that the sizes of the valves given us by the specialty people were entirely too large for practical purposes, and cut them down. We used a ½ in. valve for radiators up to 60 sq. ft. I was ready to use it for radiators up to 90 sq. ft., but the architect was afraid to take the chance. But that size was established on two large office buildings in Chicago, and I gave those jobs very careful attention through last winter and at no time was there any complaint about the radiators not getting hot and getting hot rapidly. I think myself that a ½ in. valve for a 60 sq. ft. radiator is too large for a vacuum modulation system.

Now, we have a Committee on Tests. I would like to see this committee make some tests on fractional valves under various conditions, using various types of valves, and bring in a report of their tests, giving a full description of the manner of making the tests. This is something that should be done and I believe that this Committee on Tests should be requested to submit, as soon as they can, a further report of actual test conditions of fractional valves under various conditions.

WILLIAM J. BALDWIN: I will say that the engineer of the Manhattan & Merchants Bank Building, assumed, in determining the size of these little holes, that the steam had a velocity of 900 ft. a second and the range of holes, as well as I can remember it

now, was from about a ⅛ in. for the smallest radiator, to probably ⅜ in. for the largest radiator.

One starting to experiment to determine the size of the limiting hole would do well to assume a velocity of 900 ft. a second for steam passing through a thin plate. He will not have a very large error for 1 or 2 lb. pressure. When the density of the steam increases, of course, more steam will go through the hole, but the velocity will not materially increase for low pressure heating or exhaust heating. This forms some little data with which to start fixing the size of the holes with steam at 1 lb. or thereabouts in pressure. This I know from experience.

R. L. Gifford: I think at the present time perhaps two different phases, or two separate and distinct services, are attempted in these modulation valves. Some manufacturers are working along the line of securing an orifice which, at any given differential in circulating pressure, will supply exactly the proper amount of steam which will condense in a radiator of a given size, while others are only expecting the valve to perform its natural duty of controlling the rate of steam supply. If the differential in pressure and the condensation rate were constant, it would be easy to determine the orifice which would just supply the radiator, but these conditions change every few minutes; an orifice which will just supply a radiator on a mild day and 2 lb. pressure will be away short on a cold day and a ¼ lb. pressure.

If these varying elements were constant, and the modulating valve only supplied as much steam as the radiator condensed, this would obviate the necessity of using a trap on the return end of the radiator. To actually do this, however, will require an automatic modulating valve to take into account the varying conditions.

Now, theoretically, that might be desirable, but back of it all, the essential thing is the comfort and convenience of the occupant of the room, and it strikes me that where a radiator is equipped in that manner, the size of the orifice which would supply the radiator throughout with steam, takes too long to heat.

A person coming into a cold room wants quick action rather than a split-hair adjustment on the size of the orifice. In other words, the occupants want service, and for that reason perhaps it is better to have the modulating valve, or the fractional valve, which places the control of the rate of heating and the amount of heating of the room easily within control of the occupant, simply by moving the handle in one direction to secure more heat and in the other direction less heat; and to equip the other end of the

radiator, the return end, with the trap which automatically holds the steam back in the radiator. That prevents the loss of steam into the returns, and that arrangement gives quicker heating, and, in fact, gives control of the heating to the occupant of the room.

It is, of course, a well known fact that even a ½ in. or ¾ in. valve will supply as large a heating unit as you can ever put in a room. In other words, for years we have all used radiator valves of excessive sizes. That, of course, has been handed down probably from the time of one pipe steam practice and to-day probably the limit in the size of the supply valve is not the valve itself but the size of the pipe and branch supplying the radiator; thus in reality ½ in. and ¾ in. valves are large enough for any size radiator, except that if a radiator is some distance away from the riser, so that the run-off is an inch or even 1¼ in., perhaps, it facilitates connections to use a 1 in. or 1¼ in. valve.

The Author: I do not think that there is anything in as chaotic a condition at the present time as vapor and vacuum system inlet and outlet valves. That can readily be proven and demonstrated because you can consider that the inlet valve varies between the widest extremes possible. You can find both gravity and vacuum return line systems with inlet valves varying all the way from extremely large sizes of gate valves, down to extremely small sizes of needle valves, and not satisfied with the smallest size needle valve that was ever used, they still further reduce the valve by putting a washer or a button in the seat which has a minute hole through it. That proves part of the statement, because anything which exists with these two extremes must be in an extremely broad and, I think, chaotic condition.

The outlet valves also vary in the same manner all the way from a fairly large size union elbow with absolutely no restrictions, as I mentioned in the paper, to the most efficient and modern types of valves which give scarcely any opening whatever when the radiator is hot, that is, they have an opening only of about 1/64 in. in diameter that is constantly maintained to let out the water and the little trace of air that is present. Now, any two devices which vary between these wide extremes must, to my mind, be chaotic and the chaos comes when an architect or an engineer wishes to write specifications fair to everybody, admitting the widest and fullest competition.

I have had many of them speak of this phase of the subject, the difficulty of writing an impartial specification, and I have suggested as a remedy the specifying of a result rather than a method.

The usual course is to specify some particular goods, and when they do, they usually specify goods that vary very widely; they may vary as widely almost as these valves that I have mentioned. But I have seen some of them who had really specified a result and then have had the further task, which none of them relish, of going over the things submitted by the contractors and having the danger as well as the hard work of deciding whether the device submitted will produce the result. Consulting engineers do not fancy that task because it is considerably more than double work and only those looking for work perhaps will attempt it in any degree.

The use of small sizes of valves in this line is, as I mentioned to one member to-day, about the last stand of high velocity in heating apparatus, and it is a good thing to look at things in a broad phase sometimes. At the time Mr. Tudor put in these plants, or shortly previous, we used small pipes and we used small valves so that they are nothing new, and we used high velocities. We are gradually increasing the sizes of the piping and of the valves; our boilers are almost the same size as they were. But, to my mind, about the last stand of high velocity is through these little valves. And I am wondering whether we will continue to use high velocity there, and perhaps we will go back to high velocity again. We often swing back in our practice to things we have used before and discarded. Perhaps we will increase the sizes and lose the high velocity we are using and go to low velocities.

Mention has been made of increased amounts of radiation; and we run across that question because some architects and owners get the idea that with the vapor system, a large addition in radiation is necessary. I think that some of the practice of using the larger amount of radiation has been brought about by the desire of compelling people to modulate the radiator. If you have a modulation system, make the man use it. If you put in 125 or 150 sq. ft. of radiation where only 100 sq. ft. is needed in zero weather, an occupant of the room must either open all the windows or modulate the radiator even in zero weather. In moderate weather he has to start on modulation and turn down, and he is not interested in how long it usually takes to heat the entire radiator, or even the major part of it, because he does not want it heated.

One other reason in gravity systems for increasing the amount of radiation is to help the damper regulation. I have seen many plans, and I think we have all run across them, where a building might require 1,000 sq. ft. of radiation and 1,200 or 1,300 sq. ft.

was specified. The boiler, however, is only the right size to run 1,000 sq. ft. The results are very good as far as the man who made the valves and sold the plant is concerned, but if all the radiators are left with the valves wide open you cannot keep pressure on the boiler. Therefore, you cannot make the plant inoperative because of objectionable high pressure. Again, where the radiation is all throttled and the pressure tends to run up because of a catch or hitch in the damper regulator, if the radiation is more than necessary, as the pressure goes up, more steam is forced into each radiator, which tends to keep the pressure down, therefore excessive pressure will not occur.

Concerning the regulation of these valves and the use of various devices suited to different size radiators, I have had steam-fitters working for me in New York who worked for Tudor and I have talked with them about their experiences. They said that with a small building they did not have so much trouble; they could get along with them and in small buildings there are to-day many of these systems that work very good, but where you get 200 or 300 or 500 radiators, as they have had in some of these buildings in Wall Street, it is different. I have talked with men who worked on these buildings and who regulated the valves, and they said they would not get around to make the complete circuit before they had to start all over again and then if they were away from the building a few days, some complaints might come in, whereupon the operating engineer would immediately go to the radiator and open the adjustment to its widest extent. Thus they said, the office was almost driven crazy by the additional expense and the necessity of sending men back.

It would perhaps be possible to regulate those things in France. When M. Beaurrienne was over here, I asked him how they did it over there; he said, "We do not do it as well now as we used to," and his explanation was that they had not the old, conservative workmen they used to have. Due to the growth of the business, and lots of young men coming in, mechanics, steam-fitters, engineers, of various kinds, due to the pressure of getting the work finished, they used a very small fraction of the care that these old and stable houses used some years ago. And so the "system atmospherique," as he called it, or the continental system, was not in his opinion giving nearly as much satisfaction as it used to.

We have heard to-day from one or two members about the ½ in. valve being enough for 80 or 150 sq. ft., but I have rated a ½ in. valve to 20, and a ¾ in. to 40 sq. ft. and then I have had

the architect make a specification and cut the ½ in. valve down to 15, and the ¾ in. valve down to 25 or 30 sq. ft., because they have that universal distrust of any man's rating upon any device he is interested in.

No doubt he is warranted. Yet, when a conservative list is published through this Society it should be accepted with confidence, and I would like to build up some of that confidence, so that anyone can come to the discussion of the Heating Engineers and have a little more confidence in what he finds there.

William J. Baldwin: One thing that is lost sight of is, what amount of steam passes the valve. A ½ in. valve, with 2 lb. of steam on one side, and atmosphere on the other, will pass a great deal of steam. But, in a gravity apparatus that is not the condition we have to meet. We require valves large enough to transmit the steam; not only valves but pipes sufficient to carry the steam from the source to the radiator, and into and through the radiator, and down and into the point of delivery (the return pipe). We must have them so large that they will pass the steam with an infinitesimal loss of pressure from the source to the receiver.

It is then to determine what the loss of pressure will be, that determines the size of the valve. It is not what steam will pass through the valve under a 2 lb. difference of pressure, but under an infinitesimal difference of pressure. One drawback to a fractional system is that, when the radiator is cold, and you turn it on, you have not only to overcome the normal condensation, but have to heat up the iron and the cold room for the first half hour, and to the person who is designing a fractional valve system it would be worth taking into consideration, that the orifice just big enough to maintain the radiator, when it is established, is not big enough to warm a cold room in a short time, and the person who invents, should have some means of having two sizes of orifices; one for the emergency, and the other for constant use.

Frank K. Chew: I think the reason that the Committee on Tests has not had more support, is because it has not laid out the plan or specification for testing any one particular thing, whether that is a boiler, a temperature regulator, a pipe capacity, steam trap, or what not. Conditions vary, but that is no reason why the Committee of Tests shall not make a specification that a certain apparatus shall be tested in a certain way, and give a diagram of how the different fittings shall be arranged to do it. Then, if the conditions vary, let them be taken into consideration and the second

step on conditions, giving a diagram of whatever is necessary in arrangement, and blanks for keeping records and observing expected variations.

I have been saying this thing for a good many years in the Society, and I believe I am right. In the first place, the Committee on Tests could not do anything, because it did not have any money, and then, in the second place, it could not do anything because it did not show any disposition to formulate plans for doing anything. Each Committee said it could not be done. Later records show that things have been done, and there have been records of tests sent to the Society, in papers by different men, which demonstrate that I was right in the first place.

I do believe, whether it is one class of apparatus or another, that it is well within the function, and I am not so sure it is not the *duty* of any man who accepts appointment on the Committee on Tests, to realize, "Now, I know about this line of work, and I will get up the plans and specifications, and the necessary diagrams, to cover all the variations, so that that thing can be tested." After you get that, the man out in San Francisco, or up in Minneapolis, or wherever he may be, who wants to know something and has no data, and has got to know it, because he is the engineer on some piece of work, goes to the Committee on Tests' methods, and can accomplish something.

I am going to be persistent enough about this to recommend it until something is done. I am going to insist that I believe the Committee on Standards has been a little bit lazy in not finding out what would be the proper thing to do. It should be decided among the members, whether or not it is justifiable. The Committee on Tests shall lay down how you shall find out whether you need this size, that size, or the other size of something, to produce a certain result. I believe that is well within their function. I believe that, to the extent that I secured action at one of the Annual Meetings of the Society, on a proposition that one-half of the initiation fees should be set aside and divided into two funds, one for a reserve fund, and the other a research fund. Up to the present time the Society has been so poor that it could not afford to do that; it needed the money that came in the form of initiation fees, to keep the Society running. I expect to live to see the day when there will be funds available to have engineers work with the Committee. If we hire some one man to do the work, and the Committee works with him, the members do not have to give

all their time, but some engineer has to be ready to conduct the tests.

Here I want to inject another subject, if I may. There has come to me from different sources, the suggestion that a certain portion of the dues of the Society revert to the local Chapters, to conduct their meetings. Some say that in other societies that is done. Those societies are said to bear a proportion of the expense of the Chapter. I want to point out that this Society is not yet rich enough to afford to do it, and neither do I believe it would be just to do that, for this reason: At the present time, in our Chapters there are less than 250 members, and the total membership is 700 members; 250 from that leaves 450 members who are isolated, so that they cannot readily get to Chapter meetings. Why should they be forced to pay to the support of the Chapter? I cannot quite see where that would be fair to the isolated member. He cannot get the benefit of association with the Chapter, and yet he pays dues to keep the Society going.

# No. 417

# CLEAN, PURE AIR FOR OUR CITIES

By Arthur K. Ohmes, New York

Member

THE activities of many of our Commissions, Municipal Boards, etc., are at present directed mainly to securing good atmospheric conditions within our various buildings, but hand in hand with these activities are those directed toward the prevention of undue contamination of the city atmosphere itself. The latter activities seem for the present to be confined mainly to avoiding the cinders and ashes from the smoke flues of our large manufacturing plants, but unquestionably they will be extended in the future until they include odors from automobiles and the like.

The problem of dust nuisance from a large power station has already been discussed in our proceedings in January, 1915 (see the Transactions, Vol. 21, page 232).

The object of this paper is to describe a simple apparatus for generally minimizing the dust nuisance from a typical isolated plant, of which there are many hundreds in operation in every large city. Engineers may well consider that the amount of cinders from power and heating boilers is greatly increased if a high rate of combustion per square foot of grate area becomes necessary. Similarly, an "over-loaded" condition of boilers means in almost all cases more dust and cinders.

In the case in question which represents good average isolated plant practice with an ordinary rate of combustion upon grates intended for the small sizes of anthracite coal, a number of complaints had been made by neighboring building owners of excessive cinders emitted from the chimney of the power plant. The complaints became so insistent that the Health Department finally ordered that something be done to prevent the excessive deposition

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of cinders in the neighborhood. The result was the installation of a cinder collector which was erected at the top of the smoke flue as the simplest and best means of avoiding the nuisance.

The cinder collector consists mainly of a large settling chamber which is fitted with a set of baffles so arranged as to extract the maximum amount of cinders without creating an undue resistance

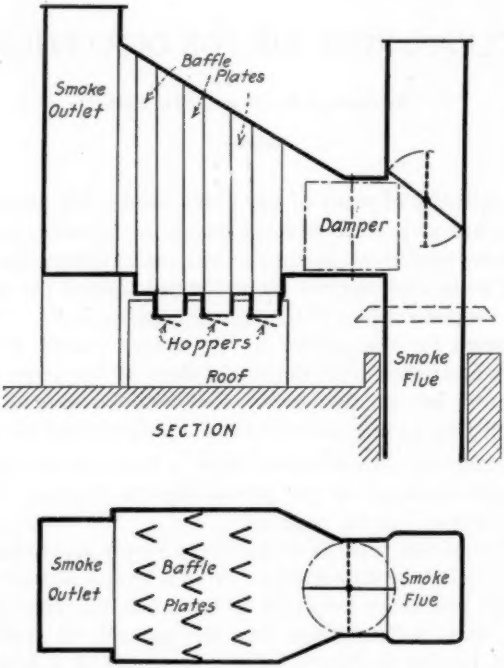


FIG. 1. DETAILS OF CONSTRUCTION OF CINDER COLLECTOR.

of the flow of the gases. The general scheme of construction is shown in the plan and section views in Fig. 1.

The apparatus has now been in successful use for several months. The cinders are removed once a week from the hoppers below the settling chamber by means of the bottom cleaning doors shown. The actual amount of cinders obtained varies greatly with the amount of coal used, as well as the percentage of ash contained in the coal. Ordinarily about 5 cu. ft. of cinders are removed weekly from the collector. This would not seem a large amount,

but the writer believes that investigation would show that this comparatively small amount of cinders would become quite a nuisance over a large area. The 5 cu. ft. would cover an area of 6,000 sq. ft. with cinders 0.01 in. high in one week's time. Such a layer of dust covering an area of 75x80 ft. would prove unquestionably most annoying, because a thickness of 0.01 in. of dust is more than ample to be very annoying.

It is to be hoped that the commendable effort made by the Health Department in this particular instance will be followed up in other cases, because the benefits which can be secured by keeping the city air in our crowded manufacturing and business districts generally as free from cinders as in the residential suburbs, will prove a boon to all who have to work and live in large cities. The writer is aware of one case where cinders from a chimney one mile away and in another case from a chimney two miles away, are plainly a nuisance.

## DISCUSSION

WILLIAM J. BALDWIN: I have been working on the dust question for a number of years and what I would like to get from some member of the Society or from some of our guests, would be a reliable method of measuring dust in the air. I have had research work under way now for a long time, and while I can get some kind of *comparative* results by observation, I would like to be able to determine the number of grains to the cubic foot, or the fraction of grains to the cubic foot by a standard method. Some of my measurements seem to indicate as high as four grains of cinders will go out of the top of a chimney per cubic foot of gas. This is excessively high, but one-tenth of a grain is very common. If there is anybody present that can suggest a method, I will be very glad to hear it.

In a chimney, in which there is a separator we put a blade 6 in. wide by 2 ft. long, through a hole, and keep it there, say five seconds, and then withdraw it. When that is done, in another hole in the flue beyond the dust separator, we introduce a second blade of similar size. These blades are covered with an oil that takes about 700 deg. to evaporate. The dust sticks to the blades; we then wash the oil off the blades, in a benzine tank like a sword sheath and filter and dry the results and weigh them. This gives us our comparative results, but our problem now is to determine the actual quantity of dust per cubic foot of air or gas. Although I have worked on that question a number of years, I am not able to answer

it very decidedly, because such a little thing in manipulation will throw a cloud on the record.

I know of chimneys in New York, that are putting out a ton of ashes every hour (24 tons of ashes in a day) and I am working on this matter as an engineer. We have got to take out 95 per cent. of the ashes, to satisfy the Board of Health of the City of New York. The ashes are so fine that 45 per cent. will go through a 200-sieve. A sieve 150 to the inch will pass 60 per cent. of it. The remainder is the cinder that falls on the roofs.

I have a little machine here that I have been working on, to catch this dust and if the members care to witness it I will give a demonstration. I have a sample of the dust that I am recovering from smelters, which is valuable dust as it contains gold and silver; these people will lay out money to recover this dust because it is valuable as a by-product.

I will explain the method from this working model and will pass the dust through the machine. I will assure you, we will catch the dust that we feed into the apparatus though the air passes freely into the room. It is to show you what can be done, mechanically, without the use of water, by a process we have been developing.

(A demonstration was given by Mr. Baldwin of a small motor driven apparatus that was effective in removing dust from the air in quantities.)

L. C. SOULE: I think Mr. Hogan may give some information on the weight of smoke and dust contained in chimney gases. He has worked with an apparatus for washing gases and may have some data with him.

THE PRESIDENT: Mr. Hogan, have you anything to say in reference to the dust removal from smoke?

E. L. HOGAN: Is it a question of measuring the quantity of dust in the air?

THE PRESIDENT: No, it is not a question of measuring the quantity; the paper is on the removal of dust. The question of measuring the dust in air, I think, is an entirely separate proposition. This is a question of the removal of the dust, such as cinders, etc., from chimneys.

E. L. HOGAN: About four years ago in conjunction with an engineer in Chicago, I designed and constructed a machine for washing smoke from chimneys in order to remove the soot and ashes. In

our experiments we found that most of the dust that came out in the gases due to the draft and their lightness, was in the form of ash. There was more dust taken out in this form than in the form of carbon or soot. We did not attempt to measure the exact quantity of dust, but we did accomplish its removal.

At that time, the theory of removing dust from gases was to bring the gases into contact with water and we found that sufficient space was not available in the average city power plant to provide sufficient water surface . We finally decided that in order to provide the necessary surface we must rotate wet surfaces and the apparatus was designed with rotating members, these members being constructed in the shape of disc fans. There were a series of these members with the water admitted between them and at the center the centrifugal force due to rotation, created a flow of water over the members. By rotating the members rapidly we obtained a large amount of wet surface of contact for the size of the equipment and actually removed the ash and carbon from the gases.

The apparatus had to be constructed of acid proof material and on account of the high cost of an equipment, nothing has been done with it. The machine was actually constructed, operated, and is still in existence. The main requisite was to obtain a large amount of wet surface of contact, which would be self-cleaning.

The amount of power required to wash the gases was small. No attempt was made to measure this quantity per 1,000 cu. ft. per min., nor was any attempt made to measure the exact quantity of dust in the gases. We simply tried to perfect apparatus to remove this dust.

H. M. Hart: Was there an induced draft with these fans?

E. L. Hogan: They were not exactly fans but were small members, set in a row, and at an angle so that they resembled a disc fan blade. In rotating, they not only passed through the gases but also created a draft sufficient to overcome the resistance of the machine. These rotating members were self-cleaning and in rotating rapidly through the gases, their wet surface presented a large amount of surface of contact.

We never collected very much data but did demonstrate what could be accomplished in washing gases, and further that in so-called smoke, more dust was in the form of ash than carbon.

Prof. John R. Allen: Some years ago we developed a device for washing smoke. We placed a large chamber in the breeching of the boiler, and with a series of water sprays in the chimney,

we succeeded in removing a great deal of carbon from the smoke. But, unfortunately, the top of the stack looked just the same. There was hardly a perceptible difference.

The water that came out was practically mud, which simply went to show that what we see in smoke is a multitude of very fine particles of carbon, and that the larger particles are not apparent. The device which we had for washing would take out the larger particles, but not the fine particles. That has always seemed to be the great difficulty with any device for washing smoke.

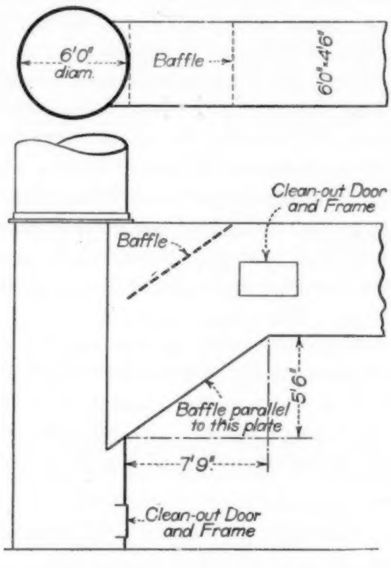


FIG. 2. CINDER COLLECTOR ARRANGED IN BREECHING.

H. M. HART: Would not the water spray tend to cool the gases and interfere with the draft?

PROF. JOHN R. ALLEN: We had an induced draft.

E. L. HOGAN: I might add that the Lake Shore R. R. has at its Englewood-Chicago roundhouse a smoke washing device. After having set up an experimental outfit at their Elkhart, Ind., shops on one locomotive, they equipped the entire Englewood roundhouse. In this instance they discharge the gases into a tank of water about 8 or 10 in. under the surface and admit steam into the discharge pipe in order to form small bubbles in the water; in this way the

gases are broken up into small bodies and thus present a large amount of wet surface. The steam is necessary to do the washing and in a considerable quantity. The gases have to be delivered at over 8 to 10 in. pressure to overcome the resistance of the water and the remainder of the system and this, together with the steam required, makes it an expensive system to operate. It does, however, remove the dust or dirt from the smoke.

H. M. HART: I will give an illustration of a simple device that has been installed in Chicago (Fig. 2). It consists merely of an inclined baffle in the breeching at the connection to the base of the stack.

It was a plant running four 200 h.p. boilers, and I think that the engineer told me that he took ashes out of the base of the stack, amounting to pretty nearly a ton a week—just cinders from that baffle. This shows that a very simple device can be installed, that will materially assist with the removal of heavy cinders. It does not clear the smoke, but it takes out the cinders, and the results on the roof of the building were very apparent. It did not seem to interfere with the draft.

## No. 418

# COMMERCIAL DRYING APPARATUS

By L. P. Dwyer,* Chicago, Ill.

Non-Member

THE subject of drying to the heating and ventilating engineer, is in importance probably second only to that which his title implies. Being a kindred subject and a necessary process in the manufacture of a great variety of materials, it is a highly interesting and remunerative field. The field is large and the requirements diversified; fully 75 per cent. of all manufacturing plants have occasion to use drying apparatus of some sort, the variation in the nature of their output requiring individual design in practically every instance.

The materials to be dried are as varied in form and nature as is the relative importance of the drying process. In the manufacture of some materials, the drying process determines more than any other the grade of the finished product, while in others the drying process may be of value only in decreasing the cost or time of manufacture.

While drying apparatus, as treated in this paper, will be considered to refer to equipment wherein the moisture is absorbed by air currents, there might be mentioned several types of apparatus employed in some cases where the free moisture content is excessively high. A press is sometimes used, the material being placed in a cylinder and compressed by a piston, forcing the moisture through openings provided for the purpose. The centrifugal bowl is a device serving a similar purpose; the product is placed in a bowl so arranged that when the bowl is revolved, the entrained water is thrown off by centrifugal force, the product itself being retained by a perforated plate or screen. Another method some-

* With B. F. Reynolds & Co., Chicago, Ill.

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times used is that of absorbing the moisture with some other substance; an illustration of this method is found in a plant manufacturing brass name plates. The lettering is inlaid on the plate by a chemical process and the plate washed with water; the water which does not drain off is absorbed with sawdust.

The field for such apparatus is, of course, limited to such materials as this method of treatment will not damage, and in most cases, only a portion of the moisture is removed, but economy of operation recommends such a device when it can be used.

## DESIGN

The design of a dryer is dependent almost entirely upon the nature of the material to be dried; its size and form will determine to a great extent the method of handling or moving, and its physical construction and component parts, the temperature and condition of the air in the dryer—while all factors govern to an extent the time required for drying.

The temperature and condition of the air best suited to a given material should be determined by experiment. It may be found that the temperature and humidity should vary during the process in order to produce the best results. The author has in mind a food product, which, after being left in the dryer for about two hours has a tendency to become coated, thereby preventing the inner moisture from coming to the surface. To overcome this, the material is transferred for a short time to a room where the air is practically saturated and again placed in the dryer. This method produces a firm product, uniformly dried. It is reasonable to suppose that the same results could be obtained by re-circulating the air in the dryer, but the facilities at the plant in question will not permit.

An arrangement for the re-circulation of air will be found to be of value in almost every drying installation. With many materials, such as lumber, the product should be heated to a uniform temperature before any material drying takes place. This is accomplished by re-circulating all the air when the apparatus is started and gradually decreasing the relative humidity of the air entering the dryer as the process progresses. It will sometimes be found that the air is being exhausted before reaching a relative humidity consistent with efficient operation. Such a condition is usually indicative of improper circulation of air in the dryer, excessive velocity or volume, or lack of sufficiently intimate contact between the material and air currents. This condition cannot always be avoided, but a considerable saving in the cost of heating will be effected by re-circulating a portion of the air.

The temperature of the air in the dryer is usually the maximum to which experiment has shown the material can be subjected. Because of increased capacity for moisture absorption, the required volume of air is lowest at this point, and the size of the apparatus at a minimum. In most cases the cost of operation is also less than with a low temperature and a proportionately increased volume.

An accurate determination of the moisture contained in the material is essential. An average condition of the air entering the heater is assumed, and its relative humidity after heating determined. Knowing the moisture content of the air entering the dryer, and assuming what it may reasonably be expected to reach in passing through (usually from 60 to 75 per cent. of total saturation), the required volume can readily be determined. Sufficient allowance must be made for heat losses by radiation, and for the heat required to raise the temperature of the material and other apparatus in the dryer.

### HANDLING MATERIAL

The method of handling the material in the dryer is of the utmost importance. Wherever possible a progressive type should be used. In this type the operation may be called automatic, and with a uniform product following the same course through the dryer, a uniform result is more certain. Provision should be made to keep the product in constant, intimate contact with the drying element, the facilities for which are apparent in the progressive type. Since most drying apparatus is a process in the manufacture of a product, it should be designed to operate in harmony with other manufacturing equipment. There are a great number of materials which can be dried successfully without any handling or attention, and the saving in labor and dependability of a progressive dryer as compared with other types will warrant an increased initial cost. There are some materials, which, because of their bulk or length of the drying period, cannot be handled in this way.

### ROOM TYPE APPARATUS

The most common form of dryer is that in which the material is placed in a room or kiln. It is usually loaded on trucks or trays to facilitate handling, and currents of air passed through the dryer. A blower is usually provided for air supply, but in some cases the supply is by gravity only. The heating apparatus is usually outside of the kiln proper, all of the required heat being provided by the heated air. In the gravity type, the heating coils are in the kiln. Lumber, and most heavy, bulky products are usually dried in this way.

The spray process of milk drying operates on lines somewhat similar. The milk is condensed to about one-fifth of its original bulk in a vacuum pan, an apparatus in which the water is evaporated at a comparatively low temperature because of the vacuum (the low temperature being necessary to prevent coagulation). It is then pumped into the kiln at a point near the ceiling through atomizing nozzles at a pressure of about 800 lb. The air (at a temperature of from 250 to 350 deg. fahr.) is admitted at a point near the ceiling and exhausted at the floor line. Considerable difficulty has been experienced in preventing the dry milk powder from being carried off with the exhaust air. A rotating cylinder covered with cheesecloth, through which the air must pass, has been used, but has not been found to be entirely satisfactory. The author understands that a more efficient method is now in use whereby the powder is made to adhere to electrically charged wires, but is not familiar with the details.

Milk is also dried by a process of evaporation with direct heat. It is placed between the walls of a steam-jacketed cylinder, the solids forming a cake or crust on the cylinder after the water is evaporated. While the cost of production by the latter process is unquestionably less, a comparison of the products of the two methods is interesting: That produced by the spray process has a soft, velvety consistency and is readily dissolved in cold water, while by the cylinder process, the product is coarse, rather gritty, and not nearly so soluble. The demand for the powder made by the spray process is greater and the market price higher.

### PROGRESSIVE APPARATUS

Among the varied types of progressive apparatus, the conveying belt or screen is well adapted to some materials. The product is fed to the belt as it enters the dryer and carried through to the dry end. If possible, the belt should be built of perforated material, and the mesh made sufficiently fine to prevent the material dropping through. The efficiency of the dryer will be materially increased over that where a solid belt is used because of more intimate contact with the air currents. The belt is usually endless and built in several sections, one above the other, the upper belt discharging on the one immediately below. This has the advantage of decreasing the length of the dryer and of changing the position of the material. This type of apparatus is also well adapted to materials requiring a variation of air condition during the process, as each section of belting may be separately housed and a different air condition provided.

An apparatus somewhat similar is that of an inclined tray or screen of considerable length, the angle of the incline being insufficient to permit the material to slide by gravity. A reciprocating motion is imparted to the tray by means of an eccentric attached to a line shaft, the motion applied being sufficient to advance the material at a uniform rate through the dryer.

For materials in small units which massing to a limited extent will not damage, the revolving drum or cylinder is ideally suited. An excellent illustration of this apparatus is that employed for drying garbage, which is a part of the process of reducing the garbage for the oil it contains. The drying drum is built of steel sheets, its diameter and length being dependent upon the quantity to be dried in a given time. The drum is set in a brick housing and slightly pitched. Ports for the admission of air are provided along the drum, so designed as to retain the material when in motion. The inner circumference of the drum is fitted with a number of baffles or cascaders, extending from the feed to the discharge end.

Before entering the dryer, the surplus moisture is drained off and the product chopped to a comparatively uniform size. The garbage is then fed to the drum by a conveyor, the rotation of the drum causing the baffles to pick up the material and drop it gradually as the angle of the baffle to the perpendicular decreases. This method insures a practically constant stream of the material over the entire area of the drum, and insures excellent contact with the air currents. The dried garbage falls from the drum at the end into a conveyor which removes it from the dryer.

Heat is provided by a furnace from which the gases pass into the chamber below the drum. Doors are provided in the brick housing through which air is admitted and mixed with the furnace gases. The mixture enters the drum through the air ports at a temperature of about 400 deg. fahr., and is drawn through to the feed end by a blower and exhausted. This method of heating cannot, of course, be used with any material which contact with the furnace gases would injure and an indirect method of heating would then be used.

### AN APPLICATION

A food product of a rather delicate nature was successfully dried with an apparatus using drums for moving the material. The drying period was about ten hours, eliminating the possibility of a progressive type. The apparatus used was a number of drums walled with screens in which the material was placed. All of the

drums are filled before the plant is started, and unloaded when the product is dry. Because of the peculiar nature of the product, it could not be cascaded in the drums, and to avoid wearing the surface as much as possible, the drums had to be turned very slowly, the speed being one revolution in six minutes.

The driving mechanism was quite a problem, as the ratio in speed between the motor armature and the drum shafts was 9000 to 1. The reduction in speed could easily have been made at the motor with internal gears, but the size of a main shaft to take the entire load at the reduced speed would have been prohibitive. Also, because of limited space, countershafts were out of the question. The mechanism as installed consists of a back-geared motor driving a main shaft at about 60 r.p.m. The driving end of each of the drum shafts (fourteen in number) is fitted with a worm gear, a speed reduction also being effected between the worm gear and the line shaft. In this way, but one counter shaft of a nominal size was used.

Air was supplied by a system of ducts placed over the drums and mechanically exhausted through ducts underneath. The air was heated by steam coils, provision being made for re-circulating any portion.

This plant is a typical illustration of the great commercial demand for apparatus of this sort. It replaced a crude apparatus designed by the manufacturer, whose knowledge of the subject consisted solely of the results he wished to accomplish. In this connection, it might be well to state that his knowledge was concise and very clear—to himself; the difference between the product dried under different conditions would hardly be apparent to one unfamiliar with it. Such a condition precluded the possibility of a specific guarantee of results by the engineer, so the plant was somewhat in the nature of an experiment. An idea of its value may be had when consideration is given the fact that thousands of dollars were invested in the apparatus.

The drying of a number of products presents problems somewhat similar; an apparatus may be built which will remove the moisture, but in such a way as to be detrimental to the product. Manufacturers having had experience with apparatus of this sort are naturally skeptical, and apt to revert to the slow, crude method of drying under natural atmospheric conditions. When they are made to realize that drying apparatus is not necessarily a dispenser of intense, dry heat, but one in which any reasonable atmospheric condition can consistently be duplicated, the field of the heating and ventilating engineer will be materially broadened.

## DISCUSSION

A. S. ARMAGNAC: An inquiry came to us a short time ago from a man engaged in drying work regarding the capacity of a blower to deliver saturated air; that is, whether in drying work, it is possible for the air to absorb more than 50 per cent. of the moisture as it passes over the article being dried. He said that in his experience, air forced through a blower cannot be made to carry a humidity much in excess of 50 per cent. of saturation. I would like to ask some of the fan men whether this agrees with their experience.

FRED R. STILL: I know a blower will deliver just as much saturated air as it will if the air is dry. There is no question about that at all. Air is seldom more than 98 or 99 per cent. saturated, so that to all outward appearances, it simply is air, that is, there is no entrainment or free water. Because air is saturated or nearly saturated, has no effect on the fan.

On this topic of drying, I wrote a letter to Secretary Obert and, in fact, I discussed the matter with him some months ago, when he was here in Detroit. I told him I did not believe that the engineers of this Society fully appreciated what the future has in store for them, and they should devote more attention to the study of drying, or specialize more on it. There is hardly anything that is manufactured such as paints and varnishes, rough products of all descriptions like lumber, bricks, etc., all sorts of foundry materials, almost anything you can think of but what requires drying—except, perhaps, metals and there are even a great many of them, too, which are in pulverized form, that have to be dried during some part of the process of manufacture.

Drying offers one of the largest fields to the engineer; yet I think I might say from personal observation that the average engineer who calls himself a "Heating and Ventilating Engineer," and who should know all about it, knows little or nothing about it. Every day we see things done by engineers which are positively absurd, either failing entirely in what they are aiming at, or they go about it the wrong way. We know this from our own experience.

The regular lines of heating and ventilating have been pretty well thrashed out and are reduced down to standards very much on a par with steam engineering, but drying is not so; hence, it seems to me that the Universities should pay more attention to it as a part of the education of men who intend taking up the Heating and Ventilating branch of Engineering.

There are immense fields for the drying engineer in foreign countries, some of them not being exactly ripe yet, but the time is coming when there will be a vast field for inventive talent and the practical application of the established principles which are commonly applied in successful drying to-day.

As I said before, the principles of drying are not understood by the majority of engineers, and I think that this being such a fruitful field for study, that it is a subject for a great many discussions in this Society.

H. M. HART: There is no question that what Mr. Still has brought out, is a fact. Even Mr. Dwyer, who writes this paper, claims that his results are mostly obtained by experimentation. He does not know what results he will get when he starts out on a proposition, as there is no authority he can refer to; and he has succeeded in getting some very good installations, getting good results, but it is only by experimenting with the proposition, and working it out, correcting his mistakes as he went along.

I believe there are a great many others that are doing the same thing, and perhaps if we could get more papers on commercial drying, it might bring out some information that would be of value to all of us, and would increase the field of that work. There is a demand for it, and since the war there is a demand that cannot be supplied. People have come to us with propositions for drying dyes, and all kinds of things that we don't know what to do with. We could not handle them; we don't know what to do. We have done some experimenting, and I think that everybody in that line of work is getting up against those problems. Let us bring some of those problems up here, and give some graphic descriptions of how they were solved. There is a great field for advancement in the science of drying.

## No. 419

# HEAT TRANSMISSION CALCULATIONS

By Arthur K. Ohmes, New York

Member

SOME papers recently read before the Society and the resulting discussions, have brought forward in a conspicuous manner the difficulties and inconsistencies that exist in determining the amount of heating surface that would be necessary to heat a certain room under otherwise equal conditions. While we may rightly consider that we are far from agreement in determining the exact allowances to be made for window leakage, we should, nevertheless, by this time have accepted standards for heat transmission coefficients. A statement made at our recent Annual Meeting in regard to this matter was substantially as follows:

"They have one advantage in some foreign countries that we do not have here and that is an accepted set of standards of heat transmission coefficients. If an engineer can prove that his surfaces are computed in accordance with the standards, he cannot be sued for damages, because the fault must then be in the building construction."

Some of the members discussing this matter thought it might be instructive and interesting to follow along this line and try to interest a number of heating engineers and have them state the results in calculation of a simple heat transmission problem such as is met with in every day practice. Some twenty-five heating engineers, members of the Society, were invited to state the heating surfaces which they would place in the rooms shown in detail in the accompanying diagram, Fig. 1. Of the 25 engineers, only seven have responded for which they are entitled to a certain amount of thanks for the trouble they have gone to. It is to be hoped that on reading this paper, a number of other engineers, even though not invited, will state in writing the results of their calculation of this problem, so that their results may also be discussed at the Annual Meeting.

Presented at the Semi-Annual Meeting of The American Society of Heating and Ventilating Engineers, Detroit, Mich., July, 1916.

It was first intended to have the members state the heat transmission coefficients which they would use in these various forms of building construction, but on further consideration it was thought best to request a statement only of results, and then to tabulate them in such a way that at present only methods will be shown, instead of details of coefficients. The result of the various answers are tabulated in Table 1. It will be seen that they vary a great deal in

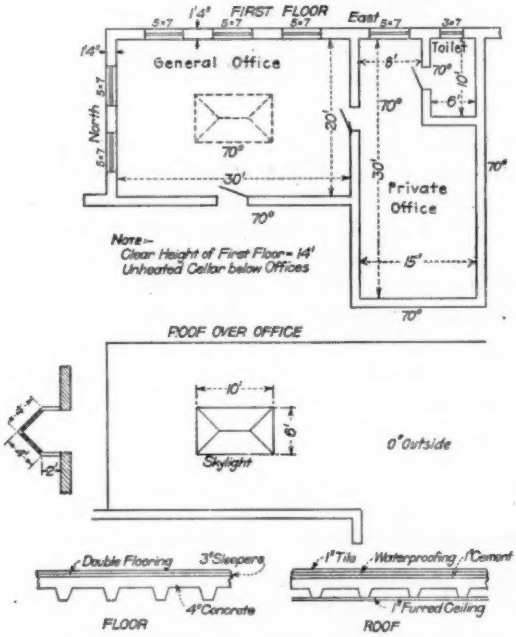


FIG. 1. TYPICAL OFFICE ROOMS FOR HEAT TRANSMISSION PROBLEM.

view of the small amount of heating surfaces required. It seems a pity that we have no accepted standards for determining that part of the work which is of vital importance to the heating engineers. There would seem to be no more reason for any variation in determining heating surfaces than there would be in determining the vital parts of an engine, a boiler, a dynamo or other form of mechanism.

The Society has at present a Committee on Standards whose activities, judging by the proceedings, have not been extensive for the reason that nothing has been published on the work of the Com-

mittee for some years past. Again we have the Committees on educational matters. But if any member of the Society should be commissioned to suggest heat transmission coefficients, he would figure out his own methods, and the possibilities would be that few other engineers would follow them, preferring to use *their* own methods instead of using methods that had not been tried by them or by any others in their locality. It is thus plainly to be seen that before the Society takes up the educational work, it should establish standards as accepted by a large number of the members of the Society as correct in factors and methods. This little discussion should also emphasize the fact that before venturing upon educational methods, it is more important to begin with research work.

Most commendable and notable work in this respect has already been accomplished by Prof. Allen, who though in an educational vocation, does not forget the importance of research work: Again judging by the paper of last year on "A Notable Institution for the Advancement of the Art of Heating and Ventilating Engineering," research work would be considered most important by our foreign engineers in heating and ventilating. It is to be hoped that the Committee on Standards will start at the bottom and let us have their version as to what may be considered a good standard for determining this simple elementary matter, that is, the proper size of radiator for a certain room. After we have this problem standardized and then the dozens of other similar and more or less important matters that go to form heating and ventilating engineering, we can proceed with full steam on our educational heating and ventilating engineering.

TABLE 1. RADIATION CALCULATED FOR TYPICAL OFFICE ROOMS.

| Heating Engineer | Main Office Radiators sq. ft. | Main Office Skylight sq. ft. | Private Office sq. ft. | Toilet sq. ft. |
|---|---|---|---|---|
| 1 | 165 | 39 | 52½ | 16 |
| 2 | 216 | 24 | 54 | 24 |
| 3 | 95 | 112 | 55 | 15 |
| 4 | 181 | 27 | 57 | 23 |
| 5 | 200 | .. | 117 | 26 |
| 6 | 165 | 18 | 32 | 19 |
| 7 | 192 | 29 | 67 | 24 |
| 8 | 180 | .. | 60 | 19 |
| Average | 174 | 31 | 62 | 21 |

## DISCUSSION

WM. J. BALDWIN (written): The object of this discussion is of course, to simplify and reduce to *some common standard* the method of proportioning heating surface for buildings. Window leakages alone are of minor importance in the proportioning of heating surface to warm rooms of buildings and the subject of proportioning the warming surfaces, within a building, to offset cooling surfaces, should not in my judgment be complicated with air leakages, or with ventilation.

Window areas and outside wall surfaces are the cooling surfaces of a building. The radiators are the heating surfaces and approximately it has been discovered, and the discovery seems to be very close to *a fact,* that 1 *square foot of radiator will counteract the cooling value of* 2 *square feet of glass in windows.*

And roughly again, it has been demonstrated that 1 *square yard* of outside wall, of ordinary house construction (as house construction existed forty years ago) was closely the equivalent of 1 square foot of glass in cooling value.

This is the foundation for the old (Baldwin) rule that ½ *square foot of radiator* would counteract the cooling effect of 1 *square foot of glass* and of 1 *square yard of wall.* This old rule has a great many advantages and it has a scientific foundation.

The loss of heat from any surface is about directly as the difference in temperature between the surface and the air that is taking away the heat. This applies to the radiator or the window. The air of the room is taking the heat from the radiator; the outside air is taking the heat from the glass.

When we work on a basis of *zero* weather, the outside air is 70 deg. cooler than the air of the room, if the air of the room is to be kept at 70 deg. fahr. When we work on the theory that our radiator has a temperature of 212 deg. fahr., then the steam of the radiator is 142 deg. hotter than the air of the room. Consequently, other things being equal, the radiator gives off practically *twice* as much heat in the same time, as a square foot of glass. This is *substantially correct,* provided the movement of the air, whether of the room or of the outside, is a natural movement; and by "natural movement" I mean the upward movement of the air at the radiator, due to the heat of the radiator, and the movement of the air outside the glass, which would be a downward movement, is in a still atmosphere.

Here we have "the two to one rule"; a square foot of radiation doing twice as much work as a square foot of glass in the transmission of heat.

Within the room there is little or nothing to accelerate the movement of the air at the radiator, except the heat of the radiator itself, which is practically a constant, varying only for the type of radiator used; while outside the glass or window we may have the action of the wind as well (if there is wind and there generally is), and the action of this wind, outside the glass, has the same effect in taking more heat through the glass that a fan would have if directed against a radiator. This statement, of course, is only approximately correct, for in the case of the radiator we are dealing with steam, whose temperature cannot be materially affected, and *twice* the air passed over it, will take practically twice the heat from it, while in the case of the glass we have air at both sides, *warm air inside* and *cold air outside,* so that the heat lost from the room, is controlled by the movement of the air both outside and inside the glass, which may be 70 deg. (or less) inside, and zero (or a little more) outside.

The reason for the loss of heat through the glass, therefore, not being dependent altogether on the movement of the outside air is that it (the loss of heat) is also dependent on the movement of the air inside the glass; so we know that the loss of heat, when the air outside (still air) is at *zero,* is not twice as great, as when the temperature outside is 35 deg. above zero. And the same reason can be given when the air outside is accelerated, for although the outside air may move twice as fast, it does not take twice as much heat from the glass of the window, for the reason that the air within the window glass falls in temperature, and does not move away sufficiently fast to maintain the original conditions of difference of temperature; so that the condition of air taking heat from air, through a glass septum, is not the same as air taking heat from steam through an iron septum. If it was, our radiators would prove entirely inadequate in very cold weather, to maintain the heat within the house. If it was not for this fact, our heating surfaces would not neutralize the loss of heat through the glass in windy weather, even assuming all to be wind tight.

Under the old rule, therefore, of ½ square foot of radiator to 1 square foot of glass, provision was made for increasing the "radiation" as found by the rule, to cover contingencies; and contingencies are leakage through windows, leakage through building materials, evaporation of moisture from walls, conductivity of building materials—for all of which it is a very difficult thing to establish a value, and even if the values were established, it would require rare judgment in using them.

Therefore, the custom has been in my office for many years to follow a rule like the following:—

> A square foot of glass has the cooling value of a square yard of wall, so that every square yard of wall is called *"the equivalent of a square foot of glass"* in cooling value and, *for each square foot of glass*, or its equivalent in wall surface, we first allow one-half square foot of radiator surface, which we modify by a *factor,* which we call *percentage.*

In other words, if it is a private residence of good construction, our radiation may be as low as "60 *per cent. of the glass value,"* or it may be increased to 125 per cent. of the glass value. 75 to 90 per cent. is the usual range. The construction would have to be very flimsy that would call for 125 per cent. Greenhouses may fall to 50 per cent. Here is where the judgment of the designer must come in.

This applies only to steam heating *at one or two pounds pressure* and it will not hold good for *hot water heating,* for the reason that the heat of the water circulation is affected by the greater cooling demand in very cold weather. Water circulation may be accelerated slightly by a greater difference of temperature within the pipes, but the acceleration is not sufficiently great to keep up the initial temperature, and this is one of the reasons that a hot water apparatus that is run on a low margin of efficiency, fails when the demand for heat is the greatest.

This subject is not complex if reduced to some simple rule, and when the greater refinements are omitted there is generally a greater measure of success.

M. WILLIAM EHRLICH (written): When an owner, builder or architect retains a consulting engineer he does so because he feels that the qualifications of the engineer—his knowledge and experience—applied to the design of any building equipment will result in the most suitable selection for the conditions. As far as a heating system is concerned, it is expected that the sizes of radiator units, piping and boilers will be proportioned to fill the requirements economically, both in first cost of equipment and in the cost of operation and maintenance.

A disagreement on an apparently simple problem would naturally bring up the pertinent and oft-repeated question:—"If experts disagree, how can the common people tell who is right or what would be the proper course to pursue?"—and a disagreement is shown by the figures in this paper!

The conditions as given in this paper seem to be the proportioning of radiator sizes for a suite of offices. The information offered as a basis is as near complete as is usually the case. What the walls are made of is not stated nor are the total depths of floor or roof given. Presumably direct steam radiation is required.

Eight heating engineers have submitted their results. One of them would provide a total of 234 sq. ft., while another would install 343 sq. ft. of direct radiation to heat the offices to 70 deg. fahr. when it is zero weather outdoors. A difference of 109 sq. ft. of surface as these two figures give, is certainly a wide discrepancy and can hardly be explained even by analysis. Why, using the thumb rule of 60 to 1 would give as near a result—245 sq. ft. based on cubical contents.

Analyzing the figures as tabulated in the paper to find why there is such a great difference shows relatively that heating engineer No. 2 computed the largest radiation for the main office, while No. 3 had the smallest surface for the same space. No. 3 again gives the highest result for the skylight and the lowest for the toilet room. No. 6 gives the smallest radiators for skylight and private office, while No. 5 gives the highest values for private office and toilet.

These figures indicate in part a lack of consistency in the use of heat loss coefficients, for the engineer's computation showing a relatively high result for one or more rooms, does not show the same characteristic for all the rooms. The results when added and compared show that engineer No. 5 would install the largest radiator, while No. 6 would provide the smallest size. Taking an arithmetical average of all the figures presented gives about 288 sq. ft. as the total radiation and this agrees with the computation of engineer No. 4. Apparently the correct result would lie between 250 and 300 sq. ft. of direct radiation and in this respect the table gives three answers over 300 sq. ft., four results between 250 and 300 sq. ft. and one size less than 250 sq. ft.

What do these variations in figures mean? The answer comes from many directions and with serious effect. Suppose, under actual conditions, there were 100 office suites similar to that in the problem and it were required to heat the building under the same climatic conditions and weather exposures.

The one who figured highest would have a total of $100 \times 343 = 34{,}300$ sq. ft.; the lowest figures would require $100 \times 234 = 23{,}400$ sq. ft. It does not seem far-fetched to assume that in the one case 40 per cent. might be allowed for pipe radiation losses and

condensation, and in the other only 20 per cent. Now, assuming that the complete installation could be made at $1.10 per square foot of radiation, the results would be:

Highest—48,020 sq. ft. × $1.10 = $52,822
Lowest—28,080 sq. ft. × $1.10 = $30,888

This shows a difference of $21,934 in the cost and installation of a heating equipment, requiring about 300 h.p. in steam boilers.

If it were necessary to compute the probable cost of operating the plant of such office building, the discrepancy on the same basis would be just as marked. The results obtained may be many times the deciding factor as to whether or not the owner should install a boiler plant, or purchase his steam from a central station supply. It may also involve the question of installing a private steam engine-driven electric plant against the purchase of electricity from the public supply as the heating load is the major factor in office building operation.

These points should emphasize the importance of deciding on standard co-efficients of heat transmission through building materials with a detailed treatment by example and illustration explaining their application. While the foregoing suggestions, intended as constructive criticism, are based only on eight years of engineering experience, in that time these very problems have recurred often and they have a significance of some importance.

To check the figures given by the other engineers in the paper, the problem was analyzed with a view of providing adequate heating. The total results, and what the basis of the figures are, together with the co-efficients used, are presented in the following table which gives 294 sq. ft. of direct steam radiation as the required total surface.

| Exposures | | | |
|---|---|---|---|
| Material | Square Feet | K for 70 Deg. | B.t.u. |
| Windows | 231 | 84 | 19,404 |
| Skylight | 100 | 78 | 7,800 |
| Wall | 165 | 17 | 2,805 |
| Floor | 1050 | 10 | 10,500 |
| Roof | 990 | 14 | 13,860 |
| Contents (Cu. Ft.) | 14700 | 1.3 | 19,110 |
| Total B.t.u. | | | 73,479 |

At 250 B.t.u. per sq. ft. radiation per hour = 294 sq. ft.

H. M. HART: It is not very strange to me, as a heating contractor, that we have this variation in the calculations of heat loss,

when I see the variations in bids on the cost of installing a heating apparatus, when every radiator, pipe and mechanism is shown in detail on the plans, and the bidders are all bidding on practically the same thing. The variation is just as great as it is on calculations of heat loss. It shows either a lot of carelessness, or else ignorance —one or the other. It is true that we lack authority, but I do not believe that the authorities that we have, would vary as much as these.

W. F. Verner: About three years ago I was trying to specialize in steam engineering and paying very little attention to heating and ventilating. At that time I had some work which caused me to take up heating and ventilating work, so I spent one year investigating relative to heating and ventilating. Naturally, I turned to The American Society of Heating and Ventilating Engineers, and started to look in the records for information on various subjects. The information I gathered was just about in this form, with a good many of the subjects, and so, of course, I had considerable difficulty in getting something concise.

I think one of the reasons for that is that a good many of the old rules have been carried along. We had rules years ago that would apply to building construction at that time, and a good many engineers have undertaken to assume different items at 25 per cent. additional, or 25 per cent. less, or 50 per cent. more, and so on. We have many rules that are not of theoretical form, and we apply them to special cases. Then we have a young fellow coming along, just starting in business, and he takes an equation and uses it. He does not know the limits of its use. I think, we should pay more attention to the theoretical form of equations. I do not mean to use the theoretical equation, but use the theoretical form, and substitute in it our constants which are arrived at by tests. The Committee on Tests should be careful of these things. That is, if we secure the results of a lot of tests, we should see that these results are put into proper form.

Fred R. Still: If Professor Allen were here he might tell you something he told the local Chapter a few nights ago, which brings out one thing that would account for some of the puzzling discrepancies in the heat transmission from radiators and how various authorities differ on factors for the figuring of heat losses. As I remember it, one statement he made was: that if it was not for the fact that zero weather prevails for only a few days at a time, no heating plant of the proportions as usually put into a building, would accomplish the heating of the building under the ordinary zero

guarantee; that, if the plants, as we are planning them, were to work continuously under zero conditions, it would take about five times as much radiation as is usually applied.

Some of the experiments he has been carrying on at Ann Arbor, as to the amount of heat transmission from radiators placed at various points in the room, and also if the exposed surfaces are inclined or whether the exposed surfaces are above or below the radiator, or what the wind pressure may be, and from which direction the wind strikes the surface, all has its effect and sometimes produces some marvelous results. The work he is doing out at Ann Arbor is going to be of very material assistance to this profession.

H. M. Hart: I think all of us who are designing heating apparatus feel the need of something authentic on heat transmission. And, it not only means that a Committee on Tests, or Standards will have to establish something authentic, but they will have to keep at it all the time. It is going to mean a pretty busy Committee, if they are going to keep up with the changes in building construction, because nearly every time we get an industrial building, a factory building, we have a different condition to deal with in the construction. They are changing the structural details—they put twenty different styles of roofs on the buildings. It is necessary to calculate how leaky the roof is going to be, and it certainly is a puzzle and results in the engineer guessing at what the loss is going to be, and then adding fifty per cent. or so as a reasonable factor of safety, to take care of probable errors.

I don't know how we are going to get what we want, until we secure a fund, so that we can pay competent engineers to devote their time to experimental work. I do not think that there are any members that have got the time and money to devote to it, outside of their business. It is going to require continual work to keep up, as every time a building structure changes, we have a different problem in front of us. I remember just recently coming in contact with a building that was put up, where the outside wall was of terra cotta blocks, open on the inside, and there was a thickness of only 1½ in. terra cotta in the outside wall, and then an air space, lathed and plastered. I was up against it to figure out what the heat loss would be through that. I insisted that inside of the terra cotta, they put a furring of tile, to create a dead air space in the terra cotta.

Another proposition is concrete, that is used so much, such as concrete floors, concrete roofs, etc. We experience serious diffi-

culty in not having any good authority on the loss through concrete roofs, of various thickness, iron roofs, etc.

I think that we will have to work and get this membership up to a thousand—then we will begin to create a fund for research work, and we certainly can keep that fund busy.

A. S. Armagnac: It may be of interest to the members, if they do not know it, to be told that the British Institution of Heating and Ventilating Engineers is now engaged in trying to establish a set of so-called "British Standard" heat loss co-efficients. The British society is very ambitious and the new standards are expected to have the same vogue as the B.t.u. standard. The idea is to develop a certain heat-loss factor through glass, for instance, and whether it is right or wrong, call it the British standard heat-loss factor for that material, and work to it. The same thing will be done with other building materials. When they get further along and find the "standard" needs modification, they will modify it. The tests that are being made to determine these standards, are being conducted by Prof. A. H. Barker at the University College in London.

James A. Donnelly: I have just added up the eight answers and averaged them, and I think perhaps it might be well to add it to the paper in the final publication, for the average of a number of answers is always interesting. I find that for the main office the average is 205 sq. ft. A year ago, at the request of the National District Heating Association, I tabulated the heat losses from buildings, and worked it up, tending towards the establishment of standard methods of figuring direct radiation. I applied the quantities, or co-efficients, which were in that paper, to these, and it figures out 220 sq. ft., so I do not think those are very far from this average, 220 to 205.

No. 420

# VENTILATION OF GARAGES

By C. W. Obert, New York

Member

SINCE the use of the gasoline automobile has become widespread, there has arisen a definite need for ventilation requirements in garages, motor car repair shops and in fact all enclosed spaces in which gasoline motors are operated. For reason of the invisibility of the exhaust gases from these motors it has been customary to operate them indiscriminately, whereas it is interesting to note that in no case would any other form of combustion device such as a stove or forge, be operated indoors, without a chimney connection. In a number of instances deaths have occurred as a direct result of confinement in limited spaces where the air has become contaminated by the exhaust gases from such motors, and in many other cases great discomfort has arisen from such continuous operation in larger spaces having inadequate facilities for ventilation.

While it is true that the cases in which deaths have occurred, have been largely those where motor vehicles have been operated in small garage buildings with the doors entirely closed, generally in cold weather, still the result is indicative of the danger that is present. Usually in such cases the motors have been operated with their carburetors poorly adjusted so as to give improper mixtures, or chemicals have been injected into the cylinders perhaps for the removal of carbon, and the result has been the formation of carbon-monoxide or some other deadly gas in sufficient quantity to cause the death of the operator from asphyxiation or gas poisoning. These occurrences have been sufficiently frequent during the past winter season for a number of health boards in various cities to have given

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serious consideration to an investigation of the entire problem of garage ventilation.

In the public garages and the motor car repair shops, the danger has been less pronounced owing to the larger interior spaces and the greater opportunity for dilution of the poisonous gases. The result is in such cases rather one of discomfort to the occupants of these spaces. The presence of such obnoxious gases is, however, undesirable for many reasons, the most notable of which are the health of the occupants and the interference with workmen who may be occupied in their presence.

In the case of the large automobile or motor manufacturing shops, it is the general practice in the motor testing rooms to provide adequate means of ventilation, as here the motors run continuously and in the development period of the industry, it was soon found that such ventilation was essential to not only the comfort, but the health, of the employees. In these large shops it is interesting to note that provisions for ventilation have been carried to the utmost extreme, exhaust arrangements being provided for all cars whose motors are required to operate for any length of time indoors. And it is the possibility of application of this practice to the cases of public and private garages that is the purpose of this paper.

Before reviewing the attempts that have been made in this direction, it may be well to point out the fact that one of the particular dangers of these deadly gases is the fact that they have practically no distinguishing odor or manifestation to warn those who may be affected, against their presence. Such gases may develop from improper carburetor adjustment or from faulty ignition in the motor, and may increase to a sufficient extent if the doors are closed to become dangerous to persons breathing that atmosphere before they become aware of any contamination. In the many cases of deaths in small garages reported during the past winter, the victim apparently made no effort to get out into the open air but merely dropped where he stood due to the quick effect of gas poisoning; he was apparently overcome so quickly as to be powerless to help himself or call for help. Herein lies the wisdom of the health boards issuing a warning to all occupants of small garages against this danger, with preferably the suggestion of possible means of prevention of the trouble.

While means for prevention of this trouble are the simplest in the small private garages, this type of building is, however, that in which such ventilation is most needed. Accordingly some of the arrangements worked out for such cases that have come to the writer's attention, will be referred to. That most generally used is

the rubber hose or flexible metal tubing with one end slipped over the outlet of the muffler pipe of the motor car, and the other end passed through the side of the building to the outer atmosphere, as shown diagrammatically in Fig. 1. This arrangement works out entirely satisfactorily provided the hose or tubing fits closely on the muffler outlet. If, however, the hose or flexible tubing is larger than the muffler outlet, the effectiveness of the arrangement is impaired as in case of a strong wind pressure on the side of the building through which the hose or tubing outlet passes, there is danger of a strong counter-current back into the interior of the garage.

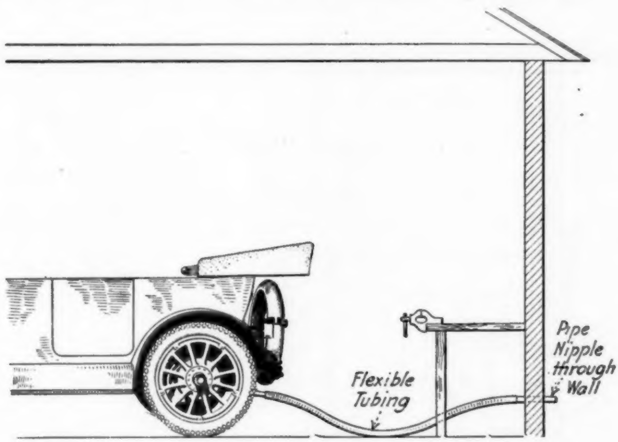


FIG 1. EXHAUST CONNECTION FOR THE TYPICAL PRIVATE GARAGE.

There is also, with that arrangement, the possibility of damage to the motor car if it should be backed out of the garage before removal of this connection. This will be evident when it is considered that in most cases motor cars are run front-on into such garages and are then necessarily backed out when leaving. If the trouble be taken to back the car in, this difficulty would not arise, as when it is run out, the hose or tubing, if left on, would automatically pull off the muffler outlet.

The more desirable arrangement is to have such hose or flexible metal tubing pass out through the roof or upper portion of the building, being suspended from the ceiling to the point of muffler connection where it would be not only convenient to apply but also be easy of access, easily seen and free from possible damage as a result of lying on the floor. If the car is liable to be run into the

garage either head foremost or backed in, it is well to provide an outlet connection at either end of the car space, or better yet, to provide one only at the rear with the stipulation that the motor shall not be run for testing purposes unless the car be backed into the garage where the muffler connection can be easily made.

For the case of the large private or public garage, the conditions are radically different in that the interior spaces are large, thus reducing the possibility of air pollution from a single motor, and also in that the opening of large doors permits frequent air changes. In cold weather, however, when the tendency is to keep doors and windows closed, the need for such ventilation becomes imperative

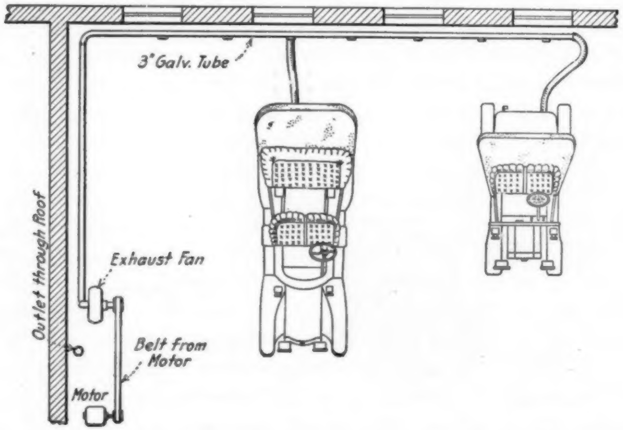


FIG. 2. EXHAUST GAS VENTILATION INSTALLATION FOR A TYPICAL MOTOR CAR REPAIR SHOP.

and it should be studied from the standpoint of both safety and comfort. In this class of garage, there are two sets of conditions that are commonly encountered, one where the motors are ordinarily operated only for shifting purposes, and the other where motors are operated continuously at times for purposes of adjusting or testing. The latter condition, which is that of the motor car repair shop also, will be considered first.

The usual tendency in the cases where motors are liable to be operated continuously is to provide for individual exhaust connection to the outlets of the mufflers, with fan suction to remove the exhaust gases to a flue or to the outside of building. An arrangement which has been used is that of an exhaust pipe carried along a side wall near the floor line with a number of plugged outlets to which flexible

conduits may be attached where desired. The connections are necessarily carried over the floor to the position in which the motor car may happen to stand. Such an arrangement is shown in Fig. 2 which illustrates the repair shop division of a large garage in New York City. In this case the exhaust main was of 3 in. galvanized iron rain conductor with 2 in. outlets soldered in at intervals, which when not in use, were kept capped. This was very effective and proved economical as the motor operating the exhaust fan was in use only when a car was under test.

In another case, a similar system was designed by the author for a motor car repair shop located in Brooklyn, N. Y., in which the

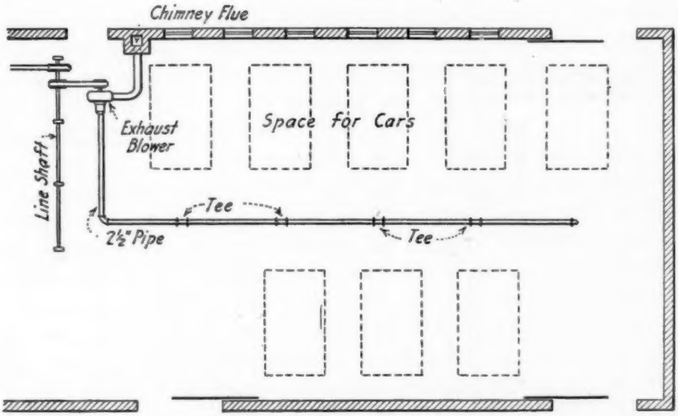


FIG. 3. AN EXHAUST GAS VENTILATING INSTALLATION WITH OVERHEAD PIPING.

exhaust main was located overhead with arrangements for connections by hose to the muffler outlets of the cars under test. This installation, which is illustrated in Fig. 3, also proved workable and economical and was entirely satisfactory. In this case the exhaust fan was belted to the line shaft in the machine shop division which adjoined the repair floor. The fan delivered into an unused chimney flue at the rear of the building and was connected on the inlet side to a 2½ in. pipe main that extended over the aisle between the two rows of cars under repairs. Tees were inserted in this main at about 8 ft. intervals with capped 1½ in. nipples pointing downward, so that a hose connection could easily be made to muffler outlet at the rear of any of the cars in position on the floor.

The cost of operation of this system was insignificant as the line shaft was running practically all of the time and the load added by

throwing on the exhaust fan was negligible. The cost of installation was also very slight as an old pressure blower was adapted for this purpose and the pipe connections were short and simple. The results were wholly satisfactory. Whereas, before installation of the system, the gases often became so dense as to cause the workmen much discomfort, with this arrangement there was no ill effect or even any odor imparted to the workroom. Its value appeared also in another way, namely, in preventing the discharge of dense smoke into the building when an overhauled motor, freshly charged with a surplus of lubricating oil, was first started; before the system was used the building customarily became filled with smoke under such

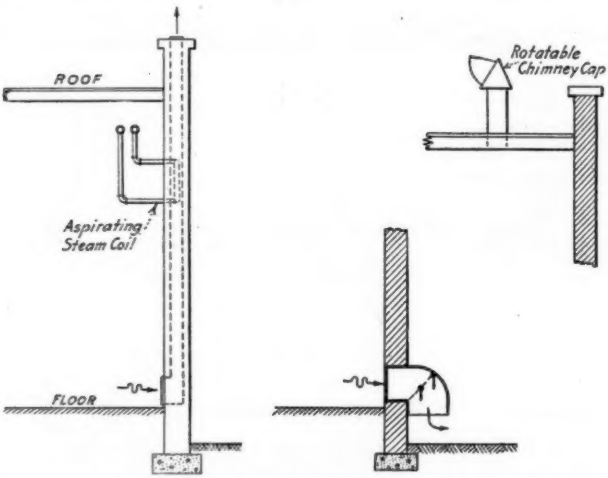


FIG. 4. FORMS OF EXHAUST FLUES SUITABLE FOR GARAGE VENTILATION.

circumstances and much discomfort was caused, as well as total stoppage of work in the shop. The exhaust system remedied this condition entirely.

In the case of shops or garage rooms where motors are ordinarily operated for purposes of shifting cars only, the necessity of exhaust systems with direct connections to the mufflers of cars is obviated, and such arrangement is, in fact, impossible owing to the uncertainty of locations of cars. Here, however, the requirement for ventilation exists for two reasons, one for the removal of exhaust gases from the motors and the other for removal of fumes of possible leaking gasoline, which involves a serious fire hazard. For the removal of the latter, floor exhaust openings are most desirable, and have been found effective for motor exhaust gases under such con-

ditions, as well. A form of exhaust flue opening such as has been used for this purpose appears in Fig. 4. The efficacy of this plan of ventilation lies in the fact that the objectionable gases which are heavier than air lie near the floor and the exhaust openings at the floor line tend to remove them first.

In a garage located at Glens Falls, N. Y., ventilation is accomplished by an improvised arrangement of a blower connected to supply fresh air through several openings near the floor line, exhaust being effected through openings near the ceiling. This would under ordinary conditions be effective in clearing the interior space except with unfavorable outside wind pressure, which might be such as to annul the effect of the blower supplying air to the interior. The natural method of avoiding this is, of course, the use of a rotatable chimney cap, or its equivalent, as shown in Fig. 4. If the foul air outlet is through the side wall, an arrangement of flap dampers, as shown also in Fig. 4, will prevent any trouble from back flow, resulting from wind pressure.

An interesting ventilation scheme is in use at the manufacturing shops of the Reo Motor Car Co., at Lansing, Mich. The completed motors are there given their block test in a high saw-tooth building, where each motor is put under heavy load against an electric dynamo. This results in an extreme heat and necessitates good ventilation. The method is to provide fresh air at the lower levels of the room and take out the heated air at the top. Several 60 in. disc exhaust fans are mounted in the different sections of the saw-tooth roof. Then at intervening points large down-take pipes supply the fresh air. These down takes make use of a sort of reverse chimney effect, inasmuch as they are filled with cold air and pass through the upper warm air region. Considerable care was taken to keep the outlets a sufficient distance from the inlets as otherwise it would result in returning the heated air to the men. In the winter time a fan heating system assists in moving the air while in the summer this is allowed to run with the coils shut off, aiding the ventilation.

## DISCUSSION

FRED R. STILL: I have had some bad experiences in this city in connection with a number of the automobile plants, in exhausting the smoke, gases and fumes from their testing rooms. It gets to be quite a problem, when dealing with as many as 120 engines all running at the same time, which there are at some of the plants in this city. One of the serious things we have encountered in that work is that while it is a comparatively easy matter to get rid of the smoke and gases, there is always a certain amount of unconsumed gas and oil which goes into the system that is not so easy to take care of, with the result that there have been some very disastrous explosions and fires. We have had two or three very bad cases of this kind.

That is an angle to the subject which has not been looked into, but should be considered when dealing with a problem of this kind. The plan now is to provide for the explosion to take place, but arrange the plant in such a way that it cannot do any harm; also provide pits or collectors where the grease and oil may be quickly and easily cleaned out. I mention this as something that should be provided for when planning an exhaust system on a large scale, as otherwise the plant will be dangerous.

H. M. HART: There was recently called to my attention, an interesting ventilating system, which was on the same principle as is shown on Fig. 2. A man came to Chicago who had patented a system for ventilation of bed pans in hospitals. He proposed to use the vacuum cleaning method, and had a flexible tube, that fitted over the nozzle of the bed pan, and connected to the vacuum cleaner outlet. It was quite a novel idea, and it was very practical. Whether it would be applied after it was installed, or not, is another question.

In Chicago, the ordinance is rather strict, concerning the building of a garage. The boiler room has to be entirely separate from the garage, and has to have an outside entrance, and in a public garage it has to have two entrances, or, it might be said, an entrance and exit. They have had some serious explosions where the fumes from a garage were taken into the boiler, with a natural draft, and the fumes became so saturated with gasoline and gas, that it resulted in an explosion.

No. 421

# HEAT TRANSMISSION THROUGH BUILDING MATERIALS

By John R. Allen, Ann Arbor, Mich.

Member

THE rate of heat transmission through building materials is a subject of fundamental importance to heating and ventilating engineers. There is much conflicting data having very little experimental foundation to establish its accuracy. About six years ago the writer constructed apparatus to determine experimentally the heat loss through building material.

This apparatus consists of a wooden box, as shown in Fig. 1. The box is 6 ft. long, 4 ft. wide and 4 ft. high on the inside. The walls are 11 in. thick and are heavily insulated with wood, air space and cork. The cross section of the insulation is shown in Fig. 2. One side of the box may be removed and in this open side the different building materials may be constructed for test purposes. The box itself is on trunnions so that it may be turned in any position, enabling the material to be tested as a floor, as a wall or as a ceiling; it is also possible, as in case of roofing material, to place the box at any angle. The box was originally placed in a room having a constant temperature so the room could be maintained at 70 deg. A brine coil was placed in the box, through which cold brine could be circulated, so that the inside of the box could be maintained at a low temperature. The difficulty, however, of weighing the brine and measuring the difference of temperature where it entered and where it left the box involved so many errors that this method was abandoned.

The box has since been placed in a shed out doors where it is free from currents of air and the box was heated. The outside of

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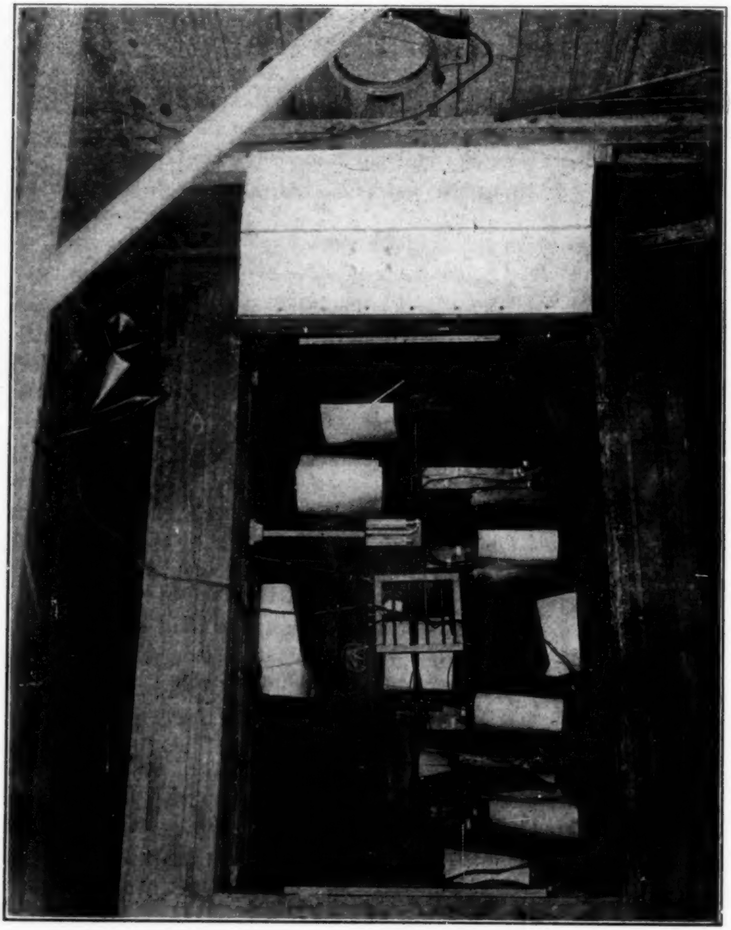

FIG. 1. INTERIOR VIEW OF WOODEN TEST BOX, SHOWING ARRANGEMENT OF THERMOMETERS AND HEATERS.

the box was subject to ordinary atmospheric conditions while the inside of the box was maintained at uniform temperature by electric heaters. These heaters consisted of ordinary carbon filament lamps, supported from a central shaft. As the box was rotated these lamps maintained the same relative positions. The electric lamps were screened by double shields of brown paper in order to reduce the radiation of heat, and protect the electrical thermometer from radiant heat. By turning the lights on and off a uniform temperature could be maintained in the box. A recording watt-

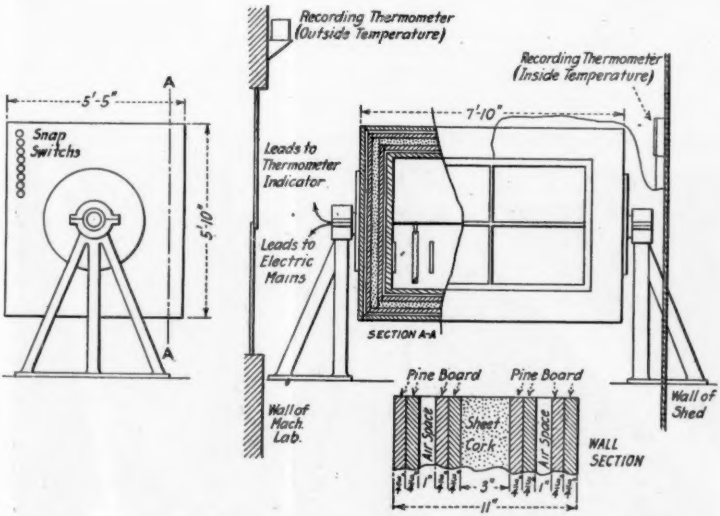


FIG. 2. DETAILS OF CONSTRUCTION OF THE WOODEN TEST BOX.

meter was used to measure the electrical energy given to the box. This electrical energy can be readily reduced to the heat equivalent.

The temperature inside of the box was determined by eight electrical thermometers placed in different parts of the box. A multiple point switch enabled the observer to read all these thermometers on one Wheatstone bridge. Before being placed in the box these thermometers were all carefully compared. A continuous recording thermometer was also used to determine the inside temperature of the box. The outside temperature of the box was determined by six mercury thermometers, each on a different side of the box. A continuous record of the outside temperature was also kept by a recording thermometer.

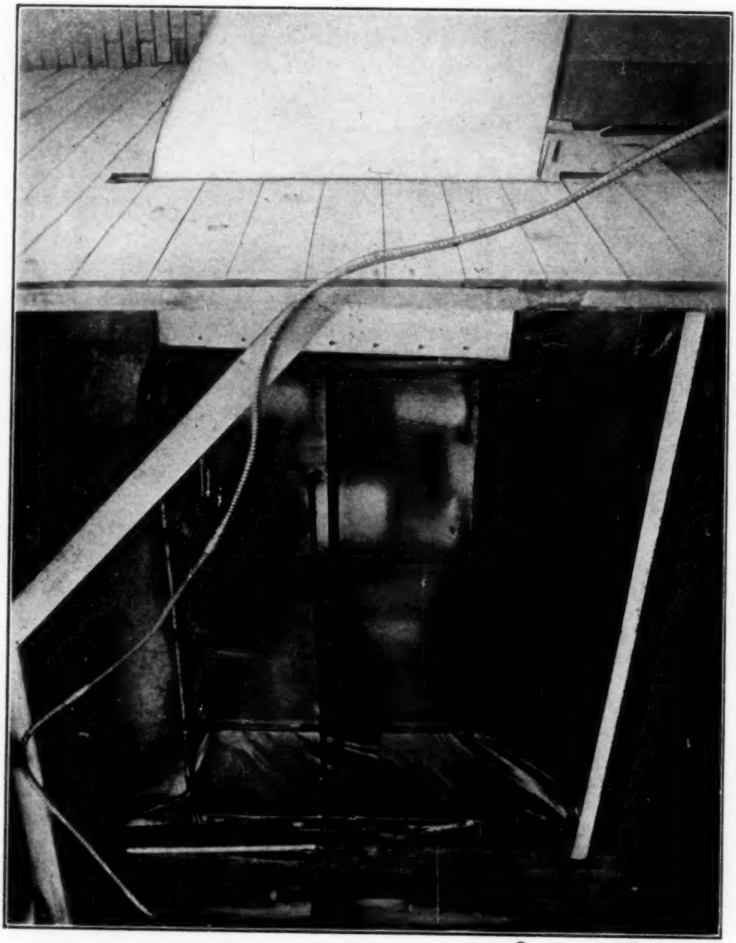

FIG. 3. VIEW OF SPRAY NOZZLES AND AIR DUCT FOR PRODUCING THE EFFECTS OF RAIN AND WIND.

In order to determine the effect of rain on the coefficient of transmission, two rows of spray nozzles were arranged so that the material to be tested might be covered by a film of water. The effect of wind was determined by delivering air in a thin film across the surface of the material to be tested, the air velocity being produced by a blower driven by an electric motor. The air was delivered across the whole length of one side of the surface of the material to be tested. The arrangement of spray nozzles and air duct is shown in Fig. 3, and of the arrangement of the instruments and heaters in the interior of the box in Fig. 4.

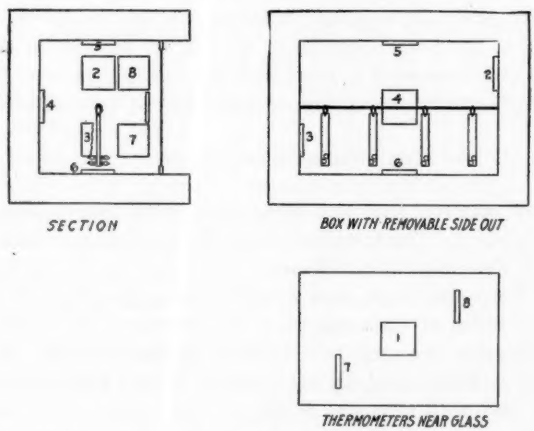


FIG. 4. DIAGRAM OF TEST BOX, SHOWING ARRANGEMENTS OF ELECTRIC THERMOMETERS AND HEATERS.

## METHOD OF TESTING

Each test was conducted with all conditions as nearly constant as possible. Particularly, care was given to maintaining a uniform difference in temperature between the inside and the outside air, and the heat input was left constant during any test or series of tests. The length of these tests was largely determined by the outside temperature, it being desirable to have a period of at least four hours of constant temperature previous to the beginning and ending of each test. Most of the tests covered a period of about 12 hours of almost constant temperature.

Other tests were made covering long periods of fluctuating outside temperature. In such cases the tests were started and finished

after at least four hours of constant outside temperature, and the temperature at the beginning and the temperature at the end were the same. This avoids the necessity of correcting for the amount of heat contained in the material of which the box is constructed.

Before commencing an experiment with any given material it is necessary to determine the radiation loss from the box itself. For this test, a side constructed in the same manner as the rest of the box was placed in the open side of the box. A coefficient was determined for the outside surface of the walls and this was applied to all the surface exposed to outside temperature. This calibration test gives a loss of 798 B.t.u.'s per hour per degree difference of temperature from the insulated sides of the box, when the center of the wall of the tested material is 10 in. from the face of the box. When the tested material is flush with the face of the box, the loss is 749 B.t.u.'s per hour per degree difference of temperature.

### CONDITIONS OF THE TEST

The only material that has been tested with this device, up to this time, is glass. The tests have been divided into two series. The first was to determine the coefficient $K$ for glass used as a window, a floor, a horizontal roof, and a roof at an inclination of 45 deg. The second series of tests was made to determine the coefficient of heat transmission for glass in a vertical position and subject to an atmosphere without wind or rain, with a violent rain, with a violent wind, and with rain and wind.

In the first series of tests the glass was set back 10 in. from the face of the box, while in the second set of tests the glass was placed flush with the face of the box.

### RESULTS OF THE TEST

The results of the tests appear in Tables 1, 2, 3 and 4, as follows:

Table 1 shows the result of the calibration test and gives the value of $K$ for the insulated box;

Table 2 shows the results of the tests for the determination of the value of $K$ for the glass in different positions;

Table 3 shows the results for the value of $K$ subject to wind and rain. The velocity of the wind was about 37 miles per hour in these tests;

Table 4 is a summary of the results and shows a probable limit for the value of $K$ for all the tests under the various conditions.

### DISCUSSION OF RESULTS

You will note from the results shown that the heat transmitted is almost the same whether glass is used as a ceiling or as a wall but when used as a floor there is a marked reduction in heat transmitted.

The second part of Table 4 gives us some idea of what a large effect wind and rain have upon the coefficient of heat transmission. The rain increases the heat transmission to a greater extent than the wind alone. Most authors assume the heat transmission through glass as 1 B.t.u. per square foot per degree difference of tempera-

TABLE 1. CALIBRATION TEST ON THE BOX WITH AN INSULATING WALL IN THE OPEN SIDE

1. Test No. 17. From 9 a. m., Feby. 27, to 6 a. m., Feby. 29; duration 45 hours.
2. Average of 7 electrical thermometers inside box, deg 94.01
3. Average of 6 mercury thermometers outside, deg... 17.91
4. Temperature difference, deg. .................... 76.10
5. Watts ....................................185.
6. B.t.u. per watt per hr. $\left\{ \frac{134x33000x60}{778x100} \right\}$ ....... 3.411
7. B.t.u. Input (3.411x185)........................630.
8. B.t.u. Loss per degree difference in temperature..... 8.2816
9. Outside surface of box, sq. ft. ....................250.8
10. "*K*" for outside surface.......................... 0.03302
11. Outside surface exposed with glass set in 10 in., sq. ft..241.8
12. Heat loss through outside surface exposed (241.8x 0.03302 B.t.u.) .............................. 7.984
13. Outside surface exposed with glass flush, sq. ft.......226.8
14. Heat loss through outside surface (226.8x0.03302 B.t.u.) ..................................... 7.489

ture but from these experiments we see that this corresponds to a condition of dry glass with a strong wind blowing. If we add to these conditions a heavy rain, the value of the coefficient is increased about 50 per cent.

While a rain never occurs in zero weather it is possible that a fine snow might occur at very low temperatures. In this case the melting of the snow on the glass would give practically the effect of a wet glass at a very low outside temperature. It would seem therefore that the coefficient used for glass should be increased.

TABLE 2. TESTS TO DETERMINE "K" FOR DIFFERENT POSITIONS OF THE GLASS.

| Test No. | 18 | 19 | 23 | 23 | 23 | 15 | 21 | 21 | 21 | 14 | 20 | 5 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Position | Glass in vertical position | | | | | Glass as a ceiling | | | | Glass as 45° skylight | | Glass as a floor | |
| Date, 1916 | 3/27 | 3/29 | 5/3 | 5/3 | 5/3 | 2/18 | 4/9 | 4/9 | 4/11 | 2/12 | 4/1 | 1/28 | 2/2 |
| Duration, hrs. | 26 | 48 | 166 | | | 11½ | 52 | | | 9 | 96 | | |
| Instantaneous Read. | | | | 8 A.M. | 8 P.M. | | | 6 A.M. | 10 A.M. | | | 1½ | 2¼ |
| Avg. Temp. inside | 89.2 | 92.2 | 139.3 | 128.2 | 131.2 | 72.1 | 85.7 | 80.2 | 87.2 | 75.1 | 91.6 | 76.2 | 78.7 |
| Avg. Temp. outside | 40.4 | 44.6 | 56.7 | 45.2 | 50.2 | 14.5 | 40.7 | 33.2 | 41.2 | 13.1 | 42.6 | 29.7 | 18.7 |
| Temp. diff. | 48.8 | 47.6 | 82.6 | 83.0 | 81.0 | 57.6 | 45.0 | 47.0 | 46.0 | 62.0 | 49.0 | 46.5 | 60.0 |
| Watts | 354 | 328 | 566 | 566 | 566 | 382 | 310 | 310 | 310 | 388 | 313 | 263 | 386 |
| B.t.u. input | 1207 | 1119 | 1930 | 1930 | 1930 | 1305 | 1058 | 1058 | 1058 | 1323 | 1067 | 895 | 1313 |
| B.t.u loss thru wooden sides | 390 | 380 | 660 | 662 | 646 | 460 | 369 | 375 | 367 | 495 | 391 | 371 | 479 |
| B.t.u. loss thru glass | 817 | 739 | 1270 | 1268 | 1284 | 845 | 689 | 683 | 691 | 828 | 676 | 524 | 834 |
| K | 0.698 | 0.647 | 0.640 | 0.637 | 0.660 | 0.611 | 0.638 | 0.606 | 0.626 | 0.557 | 0.575 | 0.470 | 0.579 |
| K corrected | 0.460 | 0.577 | 0.613 | | | | 0.525 | | | | | | |

TABLE 3. TESTS TO DETERMINE "K" FOR GLASS AS A WALL SUBJECTED TO RAIN AND WIND.

| Test No. | 24 | 24 | 26 | 26 | 26 | 26 | 28 | 28 | 29 | 29 | 30 | 31 | 31 | 33 | 33 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Condition | No wind or water | | | | | | | | Water | | Wind | Water and Wind | | | |
| Date, 1916 | 5/11 | 5/14 | 5/17 | 5/17 | 5/18 | 5/19 | 5/17 | 5/22 | 5/30 | 6/2 | 6/7 | 6/8 | 6/9 | 6/9 | 6/10 |
| Duration, hrs. | 70 | | 48 | | | | 112 | | 120 | | 12 | 6 | | 48 | |
| Instantaneous Read. | | 8 A.M. | | 6 P.M. | 6 A.M. | 6 A.M. | | 6 A.M. | | 4 A.M. | | | 6 A.M. | | 6 A.M. |
| Avg. Temp. inside | 135.8 | 133.2 | 117 | 116.2 | 119.2 | 128.7 | 122.1 | 128.7 | 106.7 | 105.7 | 108.6 | 96.7 | 95.2 | 94.2 | 92.2 |
| Avg. Temp. outside | 55.7 | 51.2 | 46.2 | 47.2 | 42.2 | 47.2 | 50.4 | 54.2 | 62.9 | 61.2 | 58.5 | 54.7 | 54.2 | 55.8 | 54.2 |
| Temp. Diff. | 80.1 | 82.0 | 70.8 | 69.0 | 74.0 | 72.0 | 71.1 | 74.5 | 43.8 | 44.5 | 50.1 | 42.0 | 41.0 | 38.4 | 38.0 |
| Watts | 554 | 554 | 481 | 481 | 481 | 481 | 481 | 481 | 481 | 481 | 481 | 481 | 481 | 481 | 481 |
| B.t.u. input | 1890 | 1890 | 1640 | 1640 | 1640 | 1640 | 1640 | 1640 | 1640 | 1640 | 1640 | 1640 | 1640 | 1640 | 1640 |
| B.t.u. loss thru wood | 600 | 615 | 530 | 517 | 555 | 539 | 537 | 558 | 328 | 333 | 375 | 314 | 307 | 288 | 285 |
| B.t.u. loss thru glass | 1290 | 1275 | 1110 | 1123 | 1085 | 1101 | 1103 | 1082 | 1312 | 1307 | 1265 | 1326 | 1333 | 1352 | 1355 |
| K | 0.671 | 0.647 | 0.654 | 0.678 | 0.611 | 0.637 | 0.641 | 0.605 | 1.248 | 1.222 | 1.05 | 1.315 | 1.355 | 1.468 | 1.485 |
| K corrected | 0.693 | | 0.657 | | | | 0.601 | | | | | | | | |

The experiments show that this coefficient should be 1.48 or approximately 1.5. This would more nearly represent the maximum loss from glass than the coefficient 1 which is used at the present time.

The University of Michigan expects to carry on this line of experiments for a series of years. We shall next take up plate glass, then cement and other forms of building material. The Author wishes to acknowledge the assistance given him by J. E. Emswiler, under whose direction the tests were conducted.

TABLE 4. UPPER AND LOWER LIMITS, AND PROBABLE VALUE OF "K" FOR ALL TESTS

I. Glass subject to ordinary atmospheric conditions and set in 10 inches from the face of the box.

| | Limits | Probable value of "K" |
|---|---|---|
| Glass vertical | 0.577-0.660 | 0.630 |
| Glass horizontal on top | 0.525-0.638 | 0.610 |
| Glass inclined at 45 deg. | 0.557-0.575 | 0.575 |
| Glass horizontal on bottom | 0.47 -0.479 | 0.47 |

II. Glass flush with the face of the box and subject to wind and rain.

| | Limits | Probable value of "K" |
|---|---|---|
| Quiet conditions | 0.601-0.693 | 0.641 |
| Rain, no wind | ........ | 1.248 |
| Wind blowing, no rain | ........ | 1.05 |
| Rain and wind | ........ | 1.485 |

## DISCUSSION

THE PRESIDENT: Professor Allen's closing remarks are something that we should give a good deal of attention to. Certainly every line in the building industry is interested in this subject, the architect and the builder and even the material man; and I cannot see why this Society would not be able to solicit pledges from various industries who want this information, would profit by it and are willing to pay for it if they know how to get it in an unbiased way, whereby they would be assured of accuracy. My ambition is to see this Society have a research fund that would be devoted to this experimental work. It wouldn't cost us so very much. In talking with Professor Allen, he tells me that for $600 a year for the man's time, we could get a graduate student to devote all of his time to this work, and some additional expense for building apparatus and structures. Certainly that is a very nominal fee when we consider the field that would be benefited by it.

M. W. FRANKLIN: I would like to ask Professor Allen whether he has done anything or has any definite plans for determining the law of diffusion of heat through these various materials as affected by the thickness. There is a mathematical theory for diffusion under different conditions with regular variations in thickness; but so far as I am aware this law has been applied only to metals in which the conductivity is relatively simple. It seems to me that a great and valuable work can be done in determining what the law of diffusion as applied to building materials is; that is, having determined once the co-efficient for any standard building material, such, e.g., as the standard glass, for instance, to determine what is the diffusion for varying thicknesses of glass; or having determined a certain quality of cement, say, on which Professor Allen dwelt, to determine what is the variation in diffusion, with the variation in thickness.

If such laws were found to be accurate and easily amenable to mathematical treatment and were formulated once for all, an immense amount of valuable information would be placed in the hands of builders and others concerned with construction and building, so that given the co-efficient accurately determined for a given thickness, we could determine with certainty the amount of heat diffusion in a given temperature within, and given atmospheric conditions without, for any given thickness of cement.

J. J. BLACKMORE: I take it from Professor Allen's explanation that the glass loss is practically the same, whether taken from the side or from the top, and I also assume it would be the same if taken on an angle; but that there was a marked difference between the losses in those three conditions and that of the loss from glass in the floor. I just want to make sure that I am right in these assumptions.

I think it would also be interesting to the membership to know, how the value of "K" was corrected, so that they have an idea as to how these losses or leaks occur in making such experiments. The value that makes for a difference between our present coefficient (which is approximately 1), and the additional 50 per cent. as proposed by Professor Allen, I understand is due entirely to the presence of water on the glass, caused by rain or sleet at a time when the temperature is below the freezing point. I realize that there are times, as Professor Allen says, when the snow might be on the glass and bring about such a condition; but it is very doubtful whether we would have a condition of sleet with as low a temperature as at or nearly to zero, though we might have such storms frequently at a temperature at or about 20 deg. Some modification may be necessary in the proposed addition of 50 per cent.; though I have not the slightest doubt that extreme conditions would produce the results that Professor Allen has proven from his very interesting experiment.

There is one point I want to bring out, and that is the extreme difference of the temperatures between the inside and the outside of the box, which is about 50 deg.; the question is, in the case of a temperature difference of 22 deg., whether the ratio will be uniformly the same as with 50 deg. or greater.

E. A. MAY: I would like to know if it was assumed that the total input was lost by conduction through material, the glass in the box, and no account taken of that part which might be lost directly by radiant energy.

J. A. DONNELLY: I am surprised that the usual question of humidity, both inside and outside, hasn't come up before. I imagine, though, that the interior of the box might get very dry after continuous heating for some considerable period. There is one other interesting feature, and that is the test run at night; I have no doubt we might get some appreciation of heat from radiant energy that might stray around in the daytime. Also would it be possible or practicable to make a box entirely of glass; and then it

might be allowed to stay out in a severe snow storm and see if we could get some sleet conditions in very cold weather?

FRED W. JOHNSON: I would like to ask if there has been any effort made to determine whether the co-efficient of transmission of the glass is affected by the direction of the air current, or wind, passing over it. The point I wish to bring out is—that it would appear that the transmission of heat through the glass under the conditions of this experiment may have been greatly increased by the "wiping off" effect of the air discharged laterally over the glass at a high velocity. This condition could hardly obtain in practice and may to some extent account for the high glass co-efficient obtained by this experiment.

C. A. BLANEY: I would like to ask Prof. Allen as to what the temperature of the water was that was sprayed? Also relative to Mr. Donnelly's proposition, we have had considerable trouble in greenhouse work in estimating the amount of radiation to be used. I think it would be quite an object to have that tried out so that we could see the sleet forming like it would on a greenhouse roof or a glass surface, and as to what effect diffusion would have.

THE AUTHOR: We have not as yet developed an equation for the laws of heat governing its transmission through varying thicknesses of wall.

When we have completed our experiments on the heat transmission through concrete walls at varying thicknesses it may be possible to develop a law showing the effect of heat transmission through building walls.

Answering the question as to the effect of the position of the glass upon the heat transmission, our experiments show that the difference in heat transmission for glass in a vertical position and glass in a horizontal position show almost the same result. It would seem that there ought to be more difference. When glass is used as a floor there is a difference of almost 25 per cent.

The correction for "K" was made for differing temperature conditions. It has been assumed for varying temperature conditions that "K" is a constant and corrections are made with this assumption. That this is a fact we do not know, but it is probable that the variation of "K" is small and that the error due to making this assumption will be small.

The experiments showed a marked increase in the value of "K" when the glass was wet. At first thought it would seem that the glass could not be wet at low temperatures and that the high value of "K" would not be applicable. In certain portions of the country

as in the North-Western States, severe sleet storms often occur in extremely cold weather. The sleet striking the glass melts and produces a condition very similar to that obtained in these experiments.

Mr. May raises the question, and a very pertinent one, as to whether the heat lost through the glass is all lost by conduction. It is possible that a portion of the heat is lost by direct radiation through the glass. In my own experiments I have never been able to separate radiant heat, and conducted heat. But it is quite reasonable to suppose that part of the heat may be lost by direct radiation through the building structure. There is no reason theoretically why this should not be so, because radiant heat is not transmitted by the material itself, but by the ether between the molecules of the material. Radiant heat can therefore be transmitted through the material without in any way affecting the molecules. The difficulty of measuring radiant heat is so great that I have never been able to separate radiant heat from the heat lost by convection and conduction. These experiments are really in the province of the physicist and not in that of the engineer.

E. A. MAY: Have those experiments along that line been confirmed or otherwise?

THE AUTHOR: I do not think they have. I do not think Peclet's experiments have been repeated. We have referred to Peclet for the last 50 years. Those experiments are not absolutely correct; it is a very difficult thing to do.

E. A. MAY: The way he measured his method was fairly accurate.

THE AUTHOR: Peclet's methods were fairly accurate, but unfortunately Peclet's experiments were not made with modern apparatus. It seems to be impossible to interest physicists in these experiments at the present time. The physicist is more interested in more brilliant things than to find out what the radiant heat from a brick or a piece of concrete is. I have never been able to get physicists interested in any material substances which a man could use.

As far as humidity is concerned, we have determined the outside humidity, but in all our experiments we have not determined the humidity inside of the box—that is a suggestion I have not thought of. We thought we had enough complications now, but possibly we will have to add one more. Just how to get the thermostat inside the box and read it correctly, I don't know. Of course, if the air was very humid, moisture would be deposited on the inside of the

glass and moisture on the inside and the outside of the glass would probably give a still higher constant.

The tests, as I said, are run continuously, but where short tests are made it is done at night, to avoid the effect of the sun. The effect of the sun in making tests of radiators is very marked. We used to make tests of radiators in the attic of a building, and I could determine from reading the thermometers which side of the roof the sun was shining on. In fact, we could tell all about whether we had sun or not without looking outdoors, and that led us to abandon making tests in a room that was affected by the sun. It makes a variation almost as high as 15 per cent. in the result.

In regard to using a box made entirely of glass, the Pennsylvania State College has a box made entirely of glass. Those tests have been conducted by Professor Moyer, and I think have been reported in the *Heating and Ventilating Magazine*. The objection to that arrangement is that you have the effect of the ceiling, walls and the floor all at the same time. The constant determined by this method is an average of the effect of all the sides. In actual use of glass we almost always use it in a vertical position. We don't want the effect of the average of all these positions; it is not a glass house we are dealing with, but we are dealing with glass windows, or ordinarily with a glass ceiling, and that is why the box was constructed the way it was.

In regard to the effect of air striking against the glass, that has not been determined. That involves another set of separate experiments and there might be a difference. Of course, I think the difference of heat condition or of heat transmission due to the passage of air across the glass is due to the rapid removal of heat. Any air that comes upon the glass in any way that will create a current across the surface, and rapidly remove the heat from the glass itself, will show an increased transmission of heat. It will depend largely on the velocity of the currents of air along the glass surface itself.

In regard to the temperature of water leaving the glass, of course, when we consider water on the glass, such water as was sprayed on the glass undoubtedly carried away a certain amount of heat by direct contact of the water with the glass, and the water has raised in temperature. We did not unfortunately obtain the temperature of the water leaving the glass, but we will see if we cannot do that next time, because that would not be a very difficult thing to do. By getting the temperature of the water before it strikes the glass, and the temperature of the water as it leaves the

glass, we will get the actual amount of heat carried away by the water itself.

W. F. Verner: You say that the value of "K" was not determined for varying differences in temperature, but it seems that there are here several varying temperatures between the inside and the outside and the value of "K" is given for those. Doesn't that cover the point?

The Author: It does not give a complete range. What I hope to do is to get a range of the difference so that we can determine the constant of "K" for each difference, and then we will determine later the variation of the constant "K" and the range of difference in temperature; I think that can be done with more experiments. When we have two or three hundred experiments of similar conditions, then we can begin to plot those constants and get at the law of variation.

E. A. May: Bringing up the question of radiation, it seems to me it would explain in some measure the difference in the co-efficient based on the glass vertical and horizontal, as a roof and as a floor, because the loss from radiation against the floor, considering the temperature of the floor, would be considerably less than it would be through the outside wall, especially if there were any glass in the wall through which the radiant energy would be dissipated to the colder outside. The actual loss through radiant energy would be less to the floor than it would be the other way, and it would possibly explain some of the differences which appear. Furthermore there is less temperature difference between the air in the box at the lower portion than would exist at the top which would also account for a part of the difference. It does seem to me that the co-efficient of conduction through glass ought to be the same no matter in what position it might be. We have to explain these differences by exact facts; and if we take average temperatures, in the box, in assuming loss through horizontal surface as a roof, I think we are taking a wrong assumption for a particular co-efficient.

Wm. J. Baldwin: Might not re-radiation answer the question the gentleman just raised? When this glass is turned to the floor (I am assuming now that the rays are coming from the inside) they are thrown directly to the floor; are they not also thrown directly back again or some of them? I am bringing this up to answer the question that the gentleman has asked, and at the same

time bring up the question of re-radiation, and its effects in the experiment.

I have in mind the case of a bank president who had a warm corner room, but his desk was close to three windows facing a City Hall Square outside, and there was no such thing as re-radiation. Although the thermometers around showed everything comfortable to the ordinary man, when he would turn his back to the City Hall Square, the radiation of his body went out into space and he felt no return of the heat, as he would from a wall, and he knew it. I am mentioning this as a practical way of illustrating this subject.

Professor Allen knows that years ago (in a crude way, in the shop) I considered matters like he is now doing, and I got some crude results. They were crude but they were some guide to present practice. At the time we had nothing but Peclet & Box to go by and I think they spoke of re-radiation, did they not?

THE AUTHOR: Yes.

WM. J. BALDWIN: I think that would account for it. The experimental apparatus, which I have not yet seen, is further from the ceiling of the inclosure, than it is from the floor, and a window in this experimental cabinet may face other windows in the inclosure, so that radiation may go out into space and there is no return When the window faces the ceiling there is some return. When the window faces the floor, or is very close to it, there is some appreciable return.

W. F. VERNER: One of the previous speakers mentioned some of the causes for this range in value of the co-efficient "K" for the different positions of the glass. Adding to that we might mention the path taken by the air in contact with the glass. In the vertical position there is very little resistance offered to the air as it moves up the glass; for instance, it comes in contact with the glass at the bottom, receives heat and rises, thus aiding in the transmission of heat through the glass. When it is in an inclined position you don't have quite so much effect. Air comes in from the sides and rises in the middle, when the glass is horizontal at the top. If the glass is horizontal at the bottom the air has no chance to rise unless it passes along the glass to the edge; that action takes place very slowly. That, I think, will account in a way for this difference in "K"—more so than the radiation effect.

WM. J. BALDWIN: Some gentleman spoke of the rate of transmission through various thicknesses. I think in the ordinary thick-

nesses of glass that we have to deal with, the rate of transmission of heat, for glass of ordinary thickness, may be considered as practically negligible. In boilers that is true. We have heat outside and water inside, with ¼ in. of metal between. With the quarter inch of metal, the amount of heat transmitted in a given time, finds little or no obstruction in the transmission. The transmission is dependent upon two other things, one is the hot fire outside, and the other is the circulation of the water in the boiler. I think that is now agreed.

In the Massachusetts Institute of Technology a good many years ago, they made experiments with a copper boiler to see if they could do more work with a copper boiler than they could with an iron one. A man that had something to sell in our line, recently sent out a circular to the effect that where you are considering the surface of the coils in the hot water tanks, that for iron coils you took this one and for copper you were to take another one; that though copper is worth three times as much as iron, it was about twice as efficient in transmissive power and less would do. I know from practice—from actual experiment, putting an iron coil and a brass coil in water tanks—that it is not true judging by the rapidity with which the tanks would heat up. It is the same way with regard to the kind of glass.

I do not say that some glass will not transmit better than others, but I do not think any of them will transmit sufficiently slow (not fast) to interfere with the taking of the heat from the air on one side of the glass and passing it to the other, because with regard to the glass, the outside air is entirely warmed by the inside air *at the glass.* One air is moving, we will say, upward because it is warmer on the inside of the glass, and the other is moving downwards on the other side of the glass, and the rapidity with which they move affects the transmission and not the glass, as the glass can transmit immeasurably faster than the airs can exchange their heat.

M. W. FRANKLIN: Referring to the remarks on radiation, the radiant heat will be the same in all directions. The amount of heat radiated in one way will be the same as that radiated in any other, assuming that the source of heat is uniform. Heat conduction, on the other hand, is a function of the heat potential, between the point at which the heat is produced and the coldest body within proximity, whether it is a wall or a floor or a ceiling or anything else. The amount of heat radiated out into space, as Mr. Baldwin said, is subject to a correction factor in the amount of heat which

is reflected back. In the case of a floor it is to be expected that the amount of heat lost in its direction is less than it is in the case of any other direction, for the reason that this is a body in close proximity with the source which is reflecting heat. Some of the heat is radiated and some is conducted. Anyway the floor is warmer in any circumstance than the air in contact with the walls and the ceiling.

In the case of a building, there is no ceiling above it, that is, the ceiling of the building itself is the ultimate ceiling. Therefore the amount of heat lost through the ceiling will be expected in ordinary circumstances, in the absence of sun light or sun heat, to be a trifle greater than the loss through the walls, for the reason that the air at the ceiling, in the absence of direct heat from the sun, is liable to be somewhat colder than the air against the walls. Ordinarily there are other buildings in the vicinity which enter into the problem. I do not think the question of separating the radiant from the conducted heat, or the convection heat, is an important one, because after all it is a practical question which confronts us, and that is, the total loss of heat and how much heat gets out of the building. The loss is so delicate and so profoundly influenced by comparatively minor variations in the velocity of the air, and possibly in the proximity of other buildings, and the nearness of the earth and so forth, that a very slight variation will throw out any refined theoretical calculation. I think what is needed is precisely what Prof. Allen is producing, namely, mathematical data, actual measurements of the laws of heat with given conditions within and without, and from them we have to construct rules and publish sheets and tables to refer to in the case of buildings.

As to the heat conduction of glasses, I don't think it is important in the case of glass. I agree wholly with Mr. Baldwin that the differences in thicknesses met with in practice are so small, and the differences of temperature are usually so large that it is not material, but, when we come to bricks, concrete, wood and mortar, or walls which are compounded of various things, with air spaces in between, I think the thickness becomes a very important factor. Certainly there is a great difference in the heat losses through a 2 in. concrete wall and that lost through a 6 in. concrete wall; and the same is true of brick walls, and again the same is true of compound walls. I think it would be valuable to have some laws if these can be formulated—at least rough laws—from which you can calculate the actual loss of heat under any given conditions.

J. J. BLACKMORE: Professor Allen overlooked answering one of the questions I asked. That is, is it possible to detect any difference between the loss per degree difference when there is an extreme difference between the inner and the outer temperatures? Temperature differences run as high as 82 deg., and they run as low as 25 deg. I know ordinarily we take the temperature per degree difference as being just the same; but it is just possible in extremes that the temperature loss per degree difference, might be greater than has been calculated on. It is one of the results that might be looked for in such an experiment.

THE AUTHOR: There isn't enough data to be able to say that there is a difference; I think there is a difference. I am pretty certain that "K" is not a constant but is a variable. We have not experimented enough to determine what that variation of "K" is; but undoubtedly it varies.

In regard to the loss of glass, vertical and horizontal, we find that when horizontal as the ceiling, the loss is usually a little less than vertical. The reason for that seems to be the fact that when the glass is placed vertically we have conduction currents moving over the glass surface. When it is placed horizontally we have practically no motion along that glass. If the glass is in the interior, the entire space is in a quiescent state, and there the difference would be accounted for by the difference of the movement of the air. But, of course, at the ceiling, you have a higher temperature, and that higher temperature making a greater difference in temperature between the inside and the outside, may account for the fact that there is so little difference. That is, the high difference of temperature on the two sides of the glass in the horizontal position compensates for the movement of the air along the glass in the vertical condition.

H. M. HART: Mr. Baldwin brought out one point here that I think we are rather interested in, and that is regarding the transmission of heat through copper versus iron coils in a water heater. Perhaps I am wrong, but I have been laboring under the impression that the copper or brass coil for heating water had a much greater efficiency than iron, in fact about 50 per cent. greater. I would like to know if there is any one here that has anything further to say on that subject.

THOS. R. WOOLLEY: I think one of the big advantages of the copper heating coil in a hot water tank over an iron coil is that the greater expansion and contraction of copper with changes of temperature causes the accumulation of scale in the pipes to break

off. Therefore for long periods of operation you are assured of cleaner pipes and consequently more efficient heating surface with a copper coil than with a steel pipe coil.

THE AUTHOR: With regard to the difference in the transmission of heat through cast iron, wrought iron and copper, in most cases there is no appreciable difference. Our experiments show that in transmitting heat through radiating surfaces there is no difficulty in getting the heat through the material composing the surface, but the difficulty is in getting the heat away from the surface. In the ordinary cast iron radiator, the thickness of the material composing the radiator makes no difference in the heat transmission.

This no doubt would be the same in different forms of coils. Much more heat can be transmitted through the material itself than can be taken away from the surface. In most cases the form and the condition of the surface of the coil is more important than the material of which the coil is composed.

J. J. BLACKMORE: I have made some experiments. The supposition that brass or copper coils will heat water more rapidly than steel or iron is due to the fact that the conductivity of brass or copper is much greater than that of iron. The trade has assumed because the conductivity is greater that it must be of greater value. But, as a matter of fact, iron or steel has a conducting power sufficient to take through the heat as rapidly as the water can absorb it, even with a rapid circulation of the water. Therefore as a water heating proposition, iron is just as good as brass or copper, provided, of course, that they are equally clean and that the question of durability is not a factor.

F. H. VALENTINE: I have had considerable experience with hot water heaters in connection with central station service, and have found that the comparative efficiency of copper coil and iron coil surfaces all depends on the type of coil that you are using. I think the difference between the efficiency of the copper and iron surface lies in the time limit for heating the tank. If a unit pipe coil heater is considered immersed in a large body of water in relation to the actual heating surface, I do not think there is much difference between the relative efficiency of the copper and the iron, but if a so-called instantaneous type of heater can be used where there is a rapid circulation of a thin layer of water over a large prime heating area, then the difference in efficiency between the copper and iron is considerable.

No. 422

# NOTES ON THE TESTING OF WARM AIR FURNACES

By R. W. Davenport, Detroit, Mich.

Member

THE determination of the characteristics of a warm air furnace is attended by difficulties seemingly out of all proportion with the simplicity of the furnace itself. Having to deal with relatively large volumes of air, moving at low velocities and under low pressures, introduces a considerable obstacle in itself, since the available methods of measuring air are less accurate at such low pressure heads. A further difficulty, due to the comparatively low heat storage or heat content of the warm air furnace, which is of course practically limited to the weight of the metal alone, lies in the wide and rapid variation in temperature and velocity of warm air, making the periodic determination of values unreliable as a basis for assuming total values over longer periods, or interpolation. The necessity for preserving natural conditions of pressure and temperature of the air also complicates the procedure, for to use air at 70 deg. fahr., or under forced draft, is to entirely vitiate the results.

Perhaps the first problem encountered in conducting efficiency tests was the question of firing. The "standard" method was found to be impossible owing to the enormous error in "judging" the heat stored at starting and stopping. The alternate method was used with considerable success on long runs of 18 hours or more, but proved unreliable on shorter runs, successive tests failing to check closer than about 8 per cent. due to uncertainty as to the state of the fuel bed at starting and stopping.

In order to eliminate this uncertainty, a "balance" method was devised and has been used for some time with considerable success.

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On the principle of the Junkers calorimeter, the furnace is charged with known constant quantities of fuel hourly or oftener, and determinations of air temperatures, air velocities and flue temperatures are made at ten minute intervals, until all values are either constant, or, in the case of high combustion rates, show a regular variation with the firing. It is obvious that when this condition is reached, the output, plus the losses, balances the input and a determination of output and losses is accurate to the limits of the methods of determination. At relatively high combustion rates, the readings eventually show a regular fluctuation with each firing period, when it becomes easy to accurately total the values determined. At moderate combustion rates, however, and with a normal depth of fuel bed, the fluctuation is negligible and successive readings will check closely over long periods.

### AIR MEASUREMENT

The most difficult problem—that of determining the velocity of the warm air—has not yet had a fully adequate solution. The methods commonly used are: The anemometer, the Pitot tube and inclined manometer, and the Thomas electric meter.

The anemometer is at once the most convenient and the least accurate method. However, when calibrated under working conditions in place, in the manner described by John R. Allen in the January, 1916, issue of the Journal (see page 293 of this Volume), the accuracy is much improved. The Pitot tube and inclined manometer, which are used to check the anemometer, require careful selecting as to proportioning of orifices. Excellent results have been obtained with the American Blower Company's form of tube and gauge. The use of the Thomas meter has been somewhat limited and no data as to its results are available at this time.

### DIRECT DETERMINATION

The writer has done some experimental work looking toward the direct determination of the heat content of the warm air, which is here described in the hope that it may prove suggestive of further developments along this line. By interposing in the path of the warm air, a large cellular radiator of the type used on automobiles, a considerable proportion of the heat of the air may be transferred to water without causing an excessive pressure drop; in fact, the resistance offered by the radiator is quite comparable with the resistance of the piping and registers in a typical working installation. The temperatures of the air on each side of the "absorber" are best determined by electric resistance thermometers comprising

grids of nickel wire, the resistance of which is determined with a Wheatstone bridge. The flow of water through the absorber is adjusted to a constant value—by means of a constant level attachment or otherwise—and the temperature rise noted, preferably on Beckmann thermometers.

From the observed data, the weight of the air is calculated as follows:

$T$ = temperatures of warm air entering absorber, deg. fahr.;
$t$ = temperatures of warm air leaving absorber, deg. fahr.;
$w$ = temperatures of water entering absorber, deg. fahr.;

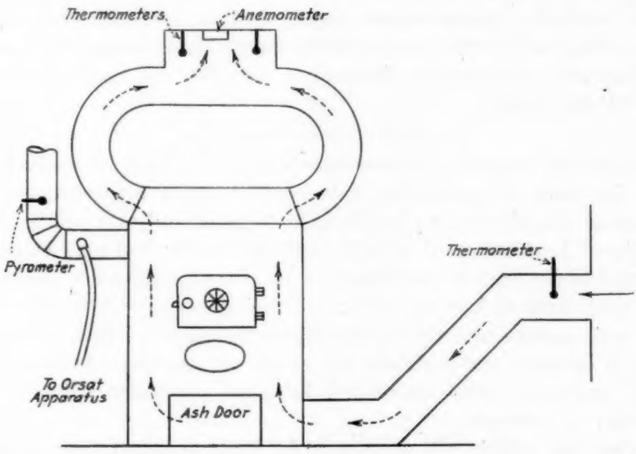


FIG. 1. ARRANGEMENT OF FURNACE CASING USED IN TESTING.

$W$ = temperatures of water leaving absorber, deg. fahr.;
$L$ = weight of water leaving absorber in lb. per min.;
$A$ = weight of air in lb. per min.

$$0.2375\ A\ (T-t) = L\ (W-w) \qquad (1)$$

$$A = \frac{L\ (W-w)}{0.2375\ (T-t)} \qquad (2)$$

The heat content of the air in B.t.u. per minute, $H$, may be calculated as follows:

If $H$ = B.t.u. per min. and
$E$ = temperature of cold air entering furnace, deg. fahr.; then

$$H = 0.2375\ (T - E)A \qquad (3)$$

It will be apparent that the accuracy of the method depends upon the accuracy of measurements on the temperature of the warm

air. This, however, is considerably greater with nickel grid resistance thermometers than with mercury thermometers for the reason that with a considerable length of nickel wire, average values are obtained throughout the area of air passages, automatically. Several factors contribute to the accuracy of the method such as the relatively great temperature drops obtainable which lessen the relative value of the errors of observation on both the water and air. Furthermore, by using the balance firing method the whole apparatus may be maintained in thermal equilibrium for considerable periods with consequent facility of observation.

It is probable that a direct reading differential arrangement of the resistance thermometers would further facilitate observation especially where the temperatures vary. It is hoped that other refinements will suggest themselves, and that the method may be developed further.

### SIGNIFICANCE OF RESULTS

Once the methods and instruments of testing have been developed to the limit of availability it becomes possible to investigate the thermal characteristics of a furnace from several viewpoints. The ratio of heat delivered to heat available in the fuel may be determined under various conditions as to rate of combustion and ratio of grate area to heating surface ("heating surface" being the area of wall surface maintained at a higher temperature than the warm air in contact) and with various lengths of gas travel between fuel bed and pipe collar, such data being of particular value in the design of furnaces.

One fact which will at once make itself apparent from a study of the data obtained on such tests, is the profound influence of the rate of combustion on the efficiency. For example, a furnace of conventional type was found to deliver to the warm air 78 per cent. of the B.t.u. content of the coal at a rate of 15 lb. per hour, while the same furnace burning 10 lb. per hour delivered 86 per cent. to the warm air.* Another furnace of similar type, but very much

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* The conditions of testing were as follows:—The furnace was a Jewel No. 31 having a grate area of about 5 sq. ft. and of stock specifications. The fuel was anthracite, fired at the rate of 10 lb. per hour, or about 2 lb. of coal per sq. ft. of grate per hour. The usual determinations of temperatures and of flue gas composition were made as in the other tests, the only difference being that, owing to the very low combustion rate, the air values were abnormally low in velocity and temperature.

The data on flue gas composition tells the story, since we obtained $O_2$—6.8 per cent.; $CO_2$—14 per cent.; CO—none, with a flue temperature of 405 deg. fahr., which according to Wm. Kent ("Steam Boiler Economy") would correspond to a loss of about 11.5 per cent. in the flue gases and would leave about 2.5 per cent. for radiation and ashpit losses which are negligible at such low rates.

smaller, showed 64 per cent. efficiency at 10 lb. per hour and 71 per cent. at 5 lb. per hour. The reason for this effect probably lies partly in the inherent characteristics of the warm air furnace which permit of relatively higher temperature limits of heating surfaces with consequent increase in radiation losses, and partly in the greatly increased flue losses at the high temperatures, and high excess air content incident to high combustion rates. By "high" rates are meant rates above 5 lb. per sq. ft. of grate, per hour. The arrangement of the furnace casing for testing is shown in Fig. 1.

An evident corollary of the above fact is that for every size of furnace the preferential combustion rates may be defined within narrow limits, with consequent advantage to all concerned.

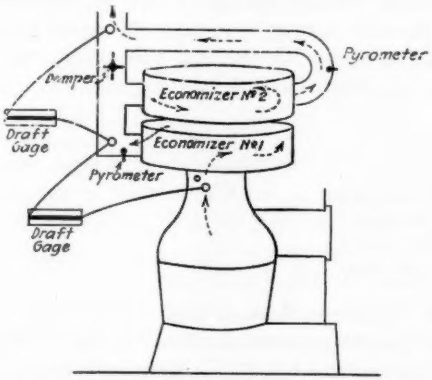


FIG. 2. DOUBLE ECONOMIZER ARRANGEMENT USED IN INVESTIGATING FLUE GAS LOSSES.

At normal and low rates of combustion, the losses in a furnace seem to be confined practically to the flue losses. Tests to establish this fact have been made in the following manner: The furnace was provided with a 1 in. insulation of asbestos felt secured to the outside of the casing by wires in such a way that it could be very

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The authority above referred to also says that "low rates of 10 lb. per sq. ft. in furnaces (boiler) produce so small a radiation loss that the furnace reaches an actual temperature nearly as high as that reached at 20 to 40 lb. per sq. ft., the loss in the latter case being due to the considerable increment of excess air necessary."

We were working at 2 lb. per sq. ft. It might be said that this rate is lower than is practicable on the job. My point, however, is that at low rates the efficiency of the warm air furnace is high to a degree unrealized. For every size of furnace the preferred combustion rates may be defined within narrow limits, and it will be self-evident, I think, that by promoting the sale of generously large furnaces, *everyone* will benefit.

quickly removed. The furnace was then "balanced" and was run in equilibrium for an hour, with nearly continuous readings of temperatures and velocities of warm air. The insulation jacket was then quickly dropped, and continuing the firing as before, the readings were carried on for another hour. The difference was within the magnitude of the inherent error—about 1.5 per cent. The combustion rate in this test was 4 lb. anthracite per sq. ft. of grate per hour, the net efficiency was 80 per cent. and the flue gas temperature was 465 deg. fahr. with a proximate analysis as follows: $O_2 = 0.101$; $CO_2 = 0.103$; $CO = 0.002$.

To further investigate the losses via flue gases, tests were made with a doubled length of gas passage in the radiator ("economizer" better describes this portion of the appliance) in comparison with a standard length of gas passage. Two economizers were superposed and dampers arranged so that the gases could be directed through both in series or through one alone, thus conveniently doubling the gas travel at will (see Fig. 2). The results were as follows:

| | Single Economizer | Double Economizer | Gain Per Cent. |
|---|---|---|---|
| Total furnace efficiency.... | 58.8 | 64.3 | 5.5 |
| Temp. drop through...... | 750°-560°=25% | 750°-460°=39% | 14.0 |
| Pres. drop (in. water).... | 0.05 | 0.06 | 0.01 (loss) |
| Final temp. waste gases.... | 560° | 460° | 17.8 |

Therefore the losses through high temperature of waste gases were reduced over 5 per cent. by doubling the length of gas travel, with the requirement of 0.01 in. increased draft pressure. The effect would of course be greater at higher rates and less at lower rates than the 15 lb. per hour (total) used on the test.

It will be evident that in all tests on the localization and magnitude of losses, the balance firing method is of great assistance since it practically insures that any change of observed values is due to the change in the arrangement of the apparatus and not to the change in rate of combustion through the burning down of the fuel bed.

It is hoped that further use of the method may be found in such work as the exploration of furnace casings for temperature and pressure distribution, in determining transmission coefficients for various surfaces at various velocities and temperature of air, and the relative value of different portions of the heating surface. And in conclusion it is hoped that the difficulties in the path of the investigation of warm air furnaces have at least been suggested temptingly enough to arouse the wider interest the question deserves.

## DISCUSSION

PROF. JOHN R. ALLEN: I would like to ask Mr. Davenport first as to the balance method of firing. Of course, the balance method of firing, as I understand it, would not give the commercial rating of the furnace; would it not be more particularly used as regards the determination of efficiency?

Another question I would like to ask is in regard to the temperature of the furnace. I see you have taken the temperature of the inside of the furnace as 750 deg.; I would like to know how the interior temperature of the furnace was determined.

W. F. VERNER: As I understand this paper it is primarily a discussion of methods for testing hot air furnaces. I was wondering if Mr. Davenport obtained satisfactory results from the tests conducted along the lines he suggests. They would be very valuable to have in order to make a study of some of the results obtained from the tests carried out along those lines.

THE AUTHOR: As to the commercial rating of a furnace as influenced by the balance method of firing, it is quite true that in ordinary commercial applications a furnace is not balanced in the sense that I use the term, and the method strictly speaking, is an instrument of research. However, the point was made that once preferential rates are determined by this or some other method, that universal benefit will result from specifying those results to the trade, and that a great deal of the difficulty experienced in adapting furnaces to practical use has been through an endeavor to run them at too high rates. Therefore, these two aspects of the question touch in their relation to the installation of the furnace only when we are able to specify the best rate at which a furnace may be run and take reasonable means to insure that it shall be run at that rate.

As to the temperature (inside) of 750 deg. fahr., the method available was by use of a nitrogen-filled thermometer and a pyrometer, which were inserted through the end of the radiator or economizer, or through an opening and which did not give the true temperature of the gases, but a composite or complex of the temperature due to radiation, and of the temperature due to the heat in the gases themselves. However, the instruments used were the same at both ends of the economizer, and since the object sought was to establish a gradient, or difference of temperature between the two ends, these methods served their purpose. We have done some

work looking forward to separating the effects of radiation and convection, but I must say that we have no worthy result yet.

As to the detailed results obtained by the methods outlined in this paper, it was not my objective to give at this time these results in detail, but rather to encourage investigation along these lines with a view ultimately to sift out from the mass of rather conflicting data, such data as can be conscientiously accepted by all of us. I therefore was and am reluctant to give in an authoritative way, such results as I have now obtained, without further opportunity for research. That applies more particularly to the efficiencies.

FRANK K. CHEW: In Professor Allen's paper in January, and in Mr. Davenport's paper now is a response to the demand of a large number of furnace users to get at some means of determining what a furnace will do. The rating of furnaces on the cubic feet of space that they will heat with no consideration of the surface exposed for heat transmission is a good deal like the question: "How big is a pound of butter?" It is very vague. Prof. Allen gives in his paper one method of testing a furnace which is similar to that used by various manufacturers for testing. It seems to me that here is somewhat of an answer to what I recommended yesterday, that the Committee on Tests should formulate a plan on which tests of different kinds should be conducted.

We have two new methods of testing furnaces, not so wonderfully different. While Prof. Allen carried his through and gave results, Mr. Davenport says that it not his purpose at this time, but he wants other people to try out methods of testing, so that after a while, from the information so provided a proper and acceptable method can be adopted. In that respect I think Mr. Davenport's paper is quite an addition to the information that is in the archives of the Society, because I believe that it is the duty of the general membership to see that the archives of the Society contain data on every subject in its field. We heard said yesterday that a man who started on something new and went into the archives of the Society, found very little there for his guidance. That is not the fault of the Past Presidents for a good many years, but that is the fault of the membership for a good many years.

I am glad to be able to point out the responsibility to these new members. There is nobody but these new young men that are coming in, to put in the archives what should be there. The function of the officers of the Society is simply to guide it and to direct it along the lines which would be most effective, and it is

for the other fellows to supply the ammunition to accomplish effective results.

In that respect, what Prof. Allen has done in the January paper, and what Mr. Davenport has done now is good. But there is something more needed, and I hope when Mr. Emswiler talks about the flow of air in pipes, he won't stop where he is now, but will go into the flow of air in furnace pipes. Very little attention has been paid to the friction between the point where the air is heated and the point where the heated air is delivered. That is another suggestion for somebody else to do the work.

No. 423

# COEFFICIENT OF FRICTION OF AIR FLOWING IN ROUND GALVANIZED IRON DUCTS

By J. E. Emswiler,* Ann Arbor, Mich.

Non-Member

THE tests described in this paper were made to determine the coefficient of friction of air flowing in round galvanized iron ducts. They constitute the first of a series of tests to be carried out in the Mechanical Laboratory of the University of Michigan for the investigation of this coefficient under a wide range of conditions, embracing different materials, cross-sectional shapes, and obstructions of various kinds.

The commonly accepted expression, connecting static pressure loss in a pipe conveying air, due to frictional effect, and velocity, is:

$$h_x = f \frac{RL}{A} \frac{V^2}{2g}$$

where $h_x$ = loss of static pressure in ft. of air:

$f$ = coefficient of friction;

$R$ = perimeter of duct in ft.;

$L$ = length of duct in ft.;

$A$ = cross-sectional area of duct in sq. ft.;

$V$ = velocity of air in ft. per sec.;

$g$ = 32.2.

(See article by J. H. Kinealy, Vol. XI of The Transactions, p. 188; also article by L. A. Harding, Vol. XIX of The Transactions, page 214.)

Inserting the data obtained from the tests into the above equation, and solving for $f$, values of the coefficient have been found for

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the different velocities and for two different sizes of round galvanized iron pipe, viz.: 6-in. and 12-in. diameter. The curves of Fig. 1 show the values of the coefficient plotted against velocity, for the two sizes of pipe.

The elements of the apparatus used in making the tests consisted of a long galvanized pipe or duct, a fan driven by belt from a motor, for producing the flow of air, and pitot tubes, together with suitable manometers, located along the pipe. Fig. 4 shows a diagrammatic layout of the apparatus.

The test pipe is of galvanized iron, made up of 28-in. lengths, fitted together by 2-in. slip joints. The longitudinal seams consist of interlocked joints, and were covered with heavy enamel paint to

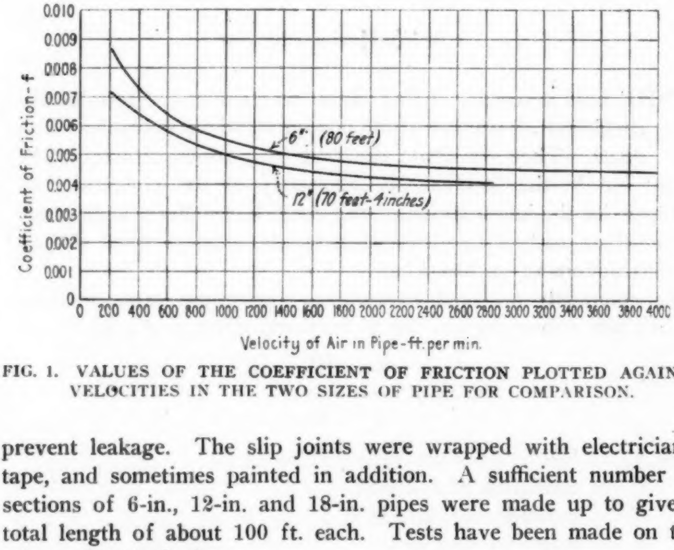


FIG. 1. VALUES OF THE COEFFICIENT OF FRICTION PLOTTED AGAINST VELOCITIES IN THE TWO SIZES OF PIPE FOR COMPARISON.

prevent leakage. The slip joints were wrapped with electricians' tape, and sometimes painted in addition. A sufficient number of sections of 6-in., 12-in. and 18-in. pipes were made up to give a total length of about 100 ft. each. Tests have been made on the 6-in. and 12-inch sizes.

A No. 4 Sirocco fan was used to furnish the flow of air. It was belted to a variable speed motor, and the velocity of air in the pipe could be varied at will by adjusting the speed of the motor.

In order to secure the necessary information about the velocity of the air and its static pressure, pitot tubes were located at three sections along the pipe. One station was about 10 or 15 ft. from the fan, another was about the same distance from the delivery end of the pipe, and the third was midway between the other two. The pipe was in this way divided into two equal sections of 35 or 40 ft. each.

Pitot tubes, of the American Blower type, were used to measure the velocity and static pressure of the air in the pipe at the different stations. The pipe was, in most cases, traversed in two planes at right angles, the final results being obtained from the average of 20 readings, 10 in each plane.

The registrations of the pitot tubes were indicated on manometers containing gasoline or kerosene, and slanted sufficiently to give a magnification of from 2 to 20 times the vertical deflection. The greatest care was necessary in the use and adjustment of these manometers because of the very minute pressures dealt with.

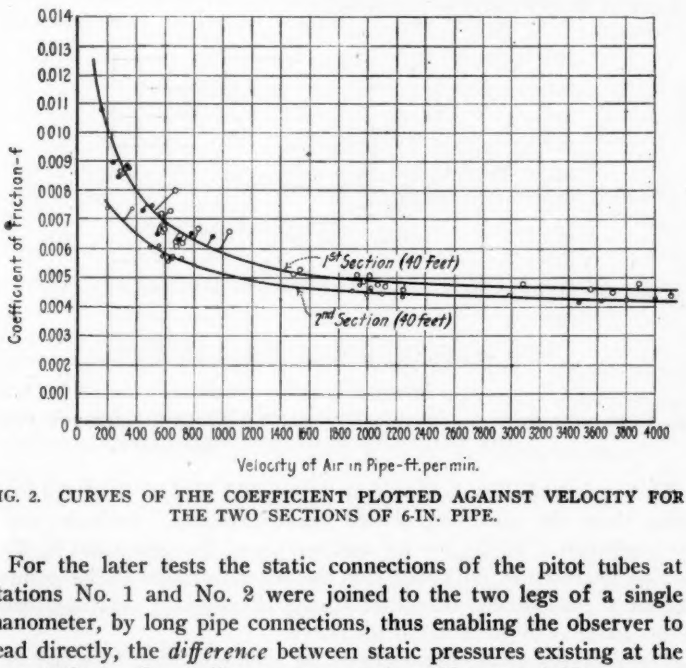


FIG. 2. CURVES OF THE COEFFICIENT PLOTTED AGAINST VELOCITY FOR THE TWO SECTIONS OF 6-IN. PIPE.

For the later tests the static connections of the pitot tubes at stations No. 1 and No. 2 were joined to the two legs of a single manometer, by long pipe connections, thus enabling the observer to read directly, the *difference* between static pressures existing at the two stations. In similar manner, stations No. 2 and No. 3 were connected (see diagram, Fig. 4).

At low velocities, the indications of velocity pressure become very small, and difficult to read. In order to get away from very low velocity head readings, a box or reservoir was connected to the delivery end of the pipe. One side of the box consisted of a plate with a number of 2-in. sharp edged orifices. Any number of orifices desired could be used. The air, in order to escape from the test pipe, had to pass into the box, then through an excelsior mat-

ting acting as a baffle to break up direct disturbing currents, and finally out through as many orifices as were open. The static pressure within the box, which could be kept high enough for easy reading, was observed and became an indication of the amount of air flowing, after the orifice coefficient had been determined.

In testing, the three pitot tubes were set in corresponding positions of the traverse, and simultaneous readings of the manometers taken. Then the tubes were shifted to the next position of the traverse, and readings again taken, and so on. Observations of temperature and barometric pressure were also taken from which the density of the air could be computed.

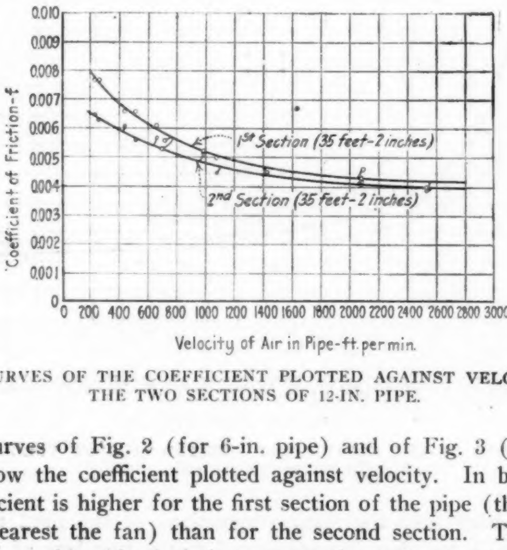


FIG. 3. CURVES OF THE COEFFICIENT PLOTTED AGAINST VELOCITY FOR THE TWO SECTIONS OF 12-IN. PIPE.

The curves of Fig. 2 (for 6-in. pipe) and of Fig. 3 (for 12-in pipe) show the coefficient plotted against velocity. In both cases the coefficient is higher for the first section of the pipe (that is, the section nearest the fan) than for the second section. The points exhibit a considerable deviation among themselves; yet there can be no doubt as to the trend of the curve.

The averages of the two sections for each pipe have been plotted to give the curves of Fig. 1.

Two points of importance are brought out by the curves. In the first place, the value of the coefficient rises rapidly with lower velocities. It may not be strictly correct to say that the coefficient varies with the velocity. More than likely, it would be nearer correct to suppose that the static loss is related to the velocity with some exponent other than 2. But since the formula already given is the one in general use, it is better to consider that the coefficient changes with velocity. The usual value for the coefficient given in

handbooks, and used in computations, is about 0.006. This appears to be a good average value, but according to the curves, is correct for only one velocity.

In the second place, the coefficient is markedly higher for the first section of the pipe than for the second. This difference is probably to be accounted for in the difference in the nature of the flow of air near the fan, and distant from it. Near the fan, the air flows with more disturbance and interference. As it passes farther along the pipe, its movement becomes more regular, and the frictional effect is less. This is verified by the very interesting fact that the center velocity of the air in the pipe near the fan is not much dif-

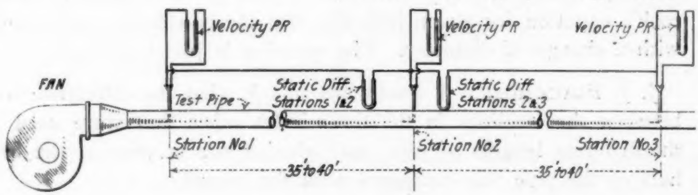


FIG. 4. THE APPARATUS USED FOR TESTS OF THE COEFFICIENT FOR ROUND GALVANIZED DUCTS.

ferent from the average velocity; while at a more distant station from the fan, the center velocity is much higher than the average, indicating that more of the air is passing through the center of the pipe, thus coming less into contact with the confining surface.

## DISCUSSION

J. R. McColl: I would like to ask Professor Emswiler how many readings for velocity he took across the pipe; how he divided the zone area for those readings.

Prof. John R. Allen: I would like to ask what effect the size of the pipe had upon the co-efficient in that form.

W. F. Verner: As Prof. Emswiler brought out, you can find some power of V so that F will become a constant. The German authorities give us this co-efficient in terms of the velocity and the perimeter, and as I recall it, these values are very close to the values that would be obtained if we used Rietschel's equations.

Another thing that is of interest is the relationship between this co-efficient and the one for steam. No doubt, most of you know that the ordinary equation for steam is derived from the equation

for the flow of air in tunnels, the experiments being made in France at one time. The difference between this co-efficient and the one for steam is simply a factor of 4. You take the area of the circular duct and you introduce $\pi/4\, d^2$. If you multiply this co-efficient for air by 4, you get the co-efficient sometimes used for steam in pipes.

Another thing of interest, is, how that co-efficient approaches a constant at high velocities. Note how it approaches the value for steam as the velocity increases. We generally run steam at velocities of 1,000 ft. or more in our steam mains, and we find this co-efficient approaches a constant value, that is, the line is almost horizontal, and the only difference is due to the diameter. Babcock's equation for steam indicates that the co-efficient varies only with a change of diameter. The question is just how much.

J. J. BLACKMORE: I would like to ask what the difference was between the readings in the three Pitot tubes that were used in the different lengths of pipe, and whether the velocity of the first half of the pipe was compared with the second?

H. M. HART: I would like to ask about the condition of the air regarding the temperature and relative humidity; if records were made of that, and if there was any loss in the temperature of the air from the inlet of the duct to the outlet?

THE AUTHOR: In answer to Mr. McColl's question, I will say that the pipe was traversed on two diameters, readings being taken at ten points on each diameter. The area of the pipe was divided into five equal concentric areas; and then each area into concentric halves by a dividing circle. The Pitot tube was placed successively on the ten intersections of each diameter with those dividing circles. The final values were therefore the result of an average of 20 readings across the pipe.

At the three stations the three Pitot tubes were all changed in position at once, and the readings taken simultaneously on corresponding positions of the traverse.

The influence of the size of the pipe on the co-efficient I think is answered in Fig. 1, in which it is shown that as far as the test of these two sizes of pipe is concerned, the co-efficient was somewhat lower for the 12 in. than for the 6 in. Whether that tendency will continue or not when we go to the 18 in. size pipe, of course, I am unable to say.

For many of the tests, the velocity in the pipe was determined at all three stations. Now, we would expect the velocity to be

the same at all three stations, provided the size of the pipe is not changed, or there is no loss of air by leakage. In nearly all our first tests the velocity was somewhat higher at the first station than at the other two, and as a rule a trifle higher at the middle station than at the last, indicating that there was a little leakage of air out of the pipe, particularly between the first and second station, where the static was higher. This leakage was finally eliminated or reduced to a negligible quantity by exercising the greatest care in sealing the joints of the sections; so that in our latest tests we feel perfectly sure in measuring velocity at one point.

J. J. Blackmore: Did you find between the walls, of say, the first station that there was a good deal of friction of the particles along the walls; was there a measurable difference in the velocity?

The Author: Across the pipe?

J. J. Blackmore: Yes.

The Author: Across the pipe, at the first station, there was not a great deal of difference in velocity at the center and at the walls, though the center velocity was somewhat higher. At the middle station, the center velocity began to forge ahead. At the last station the center velocity had forged away ahead of the wall velocity so that if the velocity were plotted on the diameter of the pipe as a base, we would have quite a steep curve, high in the center, and low at the walls. This indicates that the air had settled down to a regular condition of flow, with nearly all the air passing through the center and insulated from contact with the walls of the pipe by a cylinder of relatively slow moving air, thus reducing friction. On the other hand, at the station nearest the fan, the air is still influenced by the initial disturbances given it by the fan, and no slow moving cylinder of air can be maintained along the wall, and more friction results.

J. J. Blackmore: The velocity was calculated to be different as the report indicated; that is, for the last station, the velocity was behind the average.

The Author: The average does not differ much at the several stations, but the distribution of velocity across the section was considerably different between the first and last stations, as has just been pointed out.

As to the condition of air, the humidity and temperature, as well as the barometric pressure, were read in every case, and in determining the co-efficient, or determining the velocity, the density of

air was determined with all three variables applied. As far as any indications of a change of temperature from the time the air started into the pipe, until the time it left, we were unable to determine any change whatever. It was totally outside of the range of an ordinary thermometer, at least, to determine.

H. M. HART: May I ask at what temperature and at what relative humidity these co-efficients were established on?

THE AUTHOR: They were determined at whatever temperature or pressure or humidity happened to exist at the time.

H. M. HART: They would be variable quantities, wouldn't they?

THE AUTHOR: Yes. I have gone on the supposition, however, that this co-efficient was dependent on the density of the air and the density takes in all these three factors, so that if the density was determined, taking them into consideration, we have eliminated the influence of their variability and reduced everything to a common basis.

H. M. HART: That is for comparative purposes?

THE AUTHOR: No, for absolute results. In applying the co-efficient, we would have to go back to the formula,

$$h_x = f \frac{RL}{A} \frac{V^2}{2g}$$

With the co-efficient $f$ known, and the other variables on the right hand side known, $h_x$, the loss of pressure in feet of air due to friction, can be computed for any given case. But loss of pressure in feet of air, means but little to us, and must be converted into inches or ounces pressure, to have any significance. In making this conversion, it is necessary to know the density of air; and in order to compute the density, we must know what the barometric pressure, temperature, and humidity are for the given case. When we know these factors, we can compute definitely what the loss of pressure is in inches or ounces.

When $f$ was being determined by experiment, the barometric pressure, temperature, and humidity, all had to be observed, in order to get $h_x$. The other variables of the equation were found by observation, and then $f$ was solved for. Its value therefore takes into account the influence of pressure, temperature, and humidity, and is not a quantity that can be used only in cases where the

same pressure, temperature, and humidity prevail, but is absolute as far as they are concerned.

The President: I think we all feel the need of some up to date data on friction losses in air ducts; for practical purposes, we ought to have something that we can apply, especially on friction loss in elbows. I find that there is quite a difference among different authorities as to the friction loss in elbows. Of course, this is where they have to start. I suppose that the elbows will be coming on, and the relation of the round pipe to the rectangular pipe is what we have to get next, because we are dealing with rectangular pipes in about nine cases out of ten.

No. 424

# ENGINEERING AND COST DATA RELATIVE TO THE INSTALLATION OF STEAM DISTRIBUTING SYSTEMS IN A LARGE CITY

By F. H. Valentine, Cleveland, Ohio

**Member**

SOME of the first questions to be decided in the construction of a pipe line are its location, cost, and revenue. Location depends upon several factors, the most important of which is the ease with which the transmitting unit or pipe line may be installed from the power house to the locations of the customers.

In arriving at the cost of installation, the factors of labor, material, paving, inspection, and maintenance have to be considered.

Generally speaking the construction of underground steam mains per foot is more expensive than the construction of any other underground installation. Any operation which involves the disturbing of the street surface brings with it in addition to the usual engineering problems, a multitude of incidental ones which must be handled and solved by the engineer as a part of the whole engineering work under his charge.

The character of the soil underlying the site for the pipe line should be carefully examined in order that the foundation can be so planned as to keep the load imposed by pipe and fittings within the safe limit. For pipe lines up to and including twenty inches, with ordinary soil conditions, no special attention as to foundation is required, but the writer strongly recommends that test holes be dug at numerous points along the site of the line that the character of the soil may be determined.

The principal problem of constructing a steam line in cities is not above but below the street surface. Here you will meet with a crowded irregular alignment of sewers, water mains, gas mains,

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duct banks and distributor conduits, for telephone, telegraph, and electric power service.

Investigations of sub-surface conditions in advance of construction work will enable the engineer to determine in a general way the alignment for the steam pipe, together with such information as can be obtained from complete or incomplete records of various public service corporations and from surface indications of existing sub-surface structures. Some special investigations should, however, be made in advance of the work. These should cover points known to be exceptionally difficult or complicated, such as street intersections along the route.

### DRAWINGS

In order that the foreman may understand the scope of the work to be performed and the details of its construction, complete and accurate plans with specifications defining the methods of construction, material, etc., to be used are a necessity. It is also well to make assembled drawings showing the street and its contents in plan and as many elevations as may be necessary to make the arrangement perfectly clear. Assembled drawings insure all parts of the line fitting together properly and mistakes such as attempting to run steam pipes where water pipes exist and so on, are prevented. Twenty feet to an inch is about as small a scale as can well be used. Elevations and special details should be drawn to a scale not less than ¼ inch to the foot. All proposed locations of manholes and details of trap connections should be detailed at the larger scale.

Having determined the location for the distributing main the next step would naturally be to determine what size of pipe should be used, and in determining the size of the main or mains to be installed the following brief method is meant to be suggestive only and the discussions of the various points are omitted. First, the territory to be heated should be canvassed, carefully determining in as accurate a manner as possible the size of the present buildings, the possible life of these existing buildings and the possible future increase that might be expected for the next ten to fifteen years. The analysis of these results will give a fair approximation of the maximum load or demand that will be required at any one time on the lines. The next important step is to plot out the district in question into sections—say by streets—showing the maximum amount of radiation in demand along each section. Designate if you please the sections as Section A, B, C, etc., and from this diagram proceed to determine the size of main needed for any one section or group of sections, keeping in mind any possible extensions

that may be required. These sizes can be readily determined from the following formula known as D'Arcy's formula for flow of steam in pipes, namely:

$$d = \sqrt[5]{\frac{W^2 L}{C w (P - P')}}$$

where

d = diameter of the pipe in inches.
W = pounds of steam per minute.
w = weight per cubic foot of steam at line pressure.
(P — P') = drop in pressure.
L = length of main in feet.
C = constant depending on size of pipe and can be assumed as follows:

| | |
|---|---|
| 20″ = 62.9 | 12″ = 62.1 |
| 18″ = 62.7 | 10″ = 61.8 |
| 16″ = 62.6 | 9″ = 61.2 |
| 14″ = 62.3 | 8″ = 60.7 |

The writer would revise this formula to read thus:

$$W = C \sqrt{\frac{w (P - P') d^5}{L}}$$

then assume a size of pipe and balance the equation; after a little experience the engineer should find it easy to estimate very closely the required size without much experimenting.

Allow 3/10 of a pound of steam for each square foot of radiation per hour, which will be sufficient to supply the radiation and line losses. It is well to assume an average initial steam pressure in the lines of about 3 to 5 pounds gauge and a drop in pressure not exceeding 1 ounce for each 100 feet of run. Following out the same reasoning for all sections of the district will give the required sizes of mains.

The next important step is to so lay out this system of mains that the maximum number of customers can be supplied from the minimum number of fittings or outlets, care being taken to so locate each fitting with reference to the buildings that the shortest possible lateral may run from the main to the point of supply for the customer.

### MATERIAL

The best quality of strictly wrought iron line pipe must be secured. pipe being fitted with what is known as the long pattern line pipe couplings at all points except where fittings are placed.

A very important consideration in laying out a system of distributing pipes is the means provided for taking care of the expan-

sion of the pipes when heated. Wrought iron pipes, when placed in the ground cold, will when put under low steam pressure, expand or increase in length. Devices must therefore be installed for taking care of these repeated elongations and contractions of the pipe as the steam is turned on and off the system from season to season. As far as possible these devices should be of a nature which will not require frequent attention or expense.

Very ingenious devices known as variators are used for taking care of the expansion and contraction of lines of pipe. These expansion devices should be placed approximately 100 feet apart with an anchorage fitting, for holding the stationary portion of the pipe, placed midway between.

Flanged cross fittings should be placed at the intersections of all streets, with valves on all sides, so that extensions to the system may be made or repaired without affecting the operation of any other part of the system. The writer has learned that the initial cost of the extra valve, which may not seem necessary at first thought, is more than offset by the convenience of having it when future additions or repairs are made to any section radiating from that point.

Various other fittings such as angle joints, wedges, tees, etc., are to be figured in the estimate of material for a pipe line, but as these are dependent upon local conditions the writer does not deem it necessary to deal with them at this time.

It is not the purpose of the writer to discuss the merits of the various insulators and fittings but rather to bring out the general practice as learned from his experience.

### INSULATING STEAM MAINS

One of the first questions which presents itself in the problem of extended distribution of steam underground, is the proper protection of the distributing pipes and accessories against the loss of heat and the consequent condensation of steam. In installing conduit for steam pipes the selection should be made after determining its efficiency as a heat insulator, its initial cost and its durability. No material is an absolute non-conductor; some, however, obstruct heat passage more than others. For instance, the heat conductivity of heavy dense substances is very high; the conductivity of lighter materials is less.

Before any material can be considered a satisfactory heat insulating medium, it should be so far as possible, proof against moisture and steam. If not, the first time the line itself springs a leak or any seepage water enters, the insulation will either be ruined entirely or will be subject to rapid deterioration. It must

be able to withstand the temperatures to which it will be exposed, without affecting its physical structure. It must have a certain amount of structural strength and flexibility so that it can be applied without undue breakage and withstand vibration and ordinary wear and tear. It must protect the pipes against electrolysis; this is a very important factor in large cities.

Moreover, whatever material is used should be easy to apply and easy to get at, as that reduces the cost of installation and maintenance. It must also be reasonable in cost, taking into

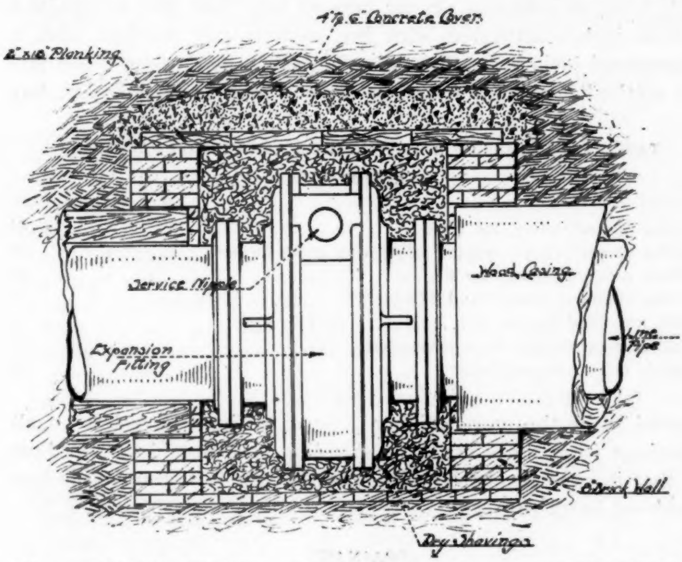


FIG. 1. SECTION SHOWING METHOD OF INSULATING UNDERGROUND STEAM FITTINGS.

consideration not only the first cost, but the cost in the long run.

The writers' practice, which has met all the factors above cited to a reasonable degree of satisfaction, is to cover the wrought-iron pipe with three thickness of asbestos paper, bound on with copper wire and then enclose it in a round, tin-lined, wood casing, having a shell 4 in. thick; a dead air space of about 1 in. is left all around the pipe, between the asbestos covering and the tin lining of the casing, the pipe being centered and supported by rollers spaced approximately 7 ft. apart. As it is necessary to have certain fixed and anchor points in the lines and as all customers' service connections are taken off from these points, it becomes necessary at intervals to break into the regular run

of pipe casing construction and to surround the various devices set at such points with a different construction. The writer's practice is to encase these fittings in a brick box 8 in. thick, extending well below and above the fitting in question, planked over on top with two-inch planking and with at least a 4 in. concrete cover over the planking to keep out any water seepage.

The writer follows two methods of insulating these fittings: One is to fill the box with dry shavings, and the other is to cover the fitting with one-inch thick felt blocks covered with a half-inch layer of asbestos plastic cement and over this to apply a canvas jacket saturated with hot asphalt and finished with a waterproof jacket of Johns-Manville asbestos roofing. The latter method, although found to have a greater initial cost, has

TABLE 1. EXCESS OF REPAVING OVER AMOUNT OF PAVEMENT REMOVED

| Kind of Pavement | Percentage of Increase |
|---|---|
| Medina dressed stone, tar filled | 44 |
| Medina dressed stone, cement filled, 6 in. concrete base | 30 |
| Medina common stone, tar filled | 43 |
| Medina common stone, sand filled | 59 |
| Brick, tar filled | 52 |
| Brick, cement filled, 6 in. concrete base | 39 |
| Asphalt, 6 in. concrete base | 36 |

proved to be the more efficient. Service nipples are left on all openings from these fittings, extending well outside of the box, so that in case of any future connection for a customer, the box need not be disturbed.

## DRAINAGE

The grading of the mains is one of the most essential features, and it becomes necessary many times to shift the location of other existing underground construction in order to provide a space for the steam main, so as not to create a pocket in the grade. When however, natural conditions or non-changeable obstructions, cause low points in the mains, provision must be made at such low points for relieving the mains of any condensation water through a steam trap into a sewer. The steam trap must in all cases be fitted with a by pass as this allows of removing without shutting down the main.

Again, if the main is divided into sections by valves, as at street intersections, provision should be made for draining each section, for the reason that some part may be shut off at times.

Beneath the entire line, except in sandy soil or soil containing large quantities of gravel, there should be placed a drain tile not less than 4 in. in diameter which at convenient points should be connected into the city sewerage system. This tile should be surrounded by broken stone.

### PAVEMENTS

Another principal factor, in actual street construction, that must meet the Engineer's attention and be given very careful thought, is the tearing up of the pavements and replacing in

TABLE 2. PAVEMENT REMOVED FOR MEDINA DRESSED STONE, TAR FILLED; MEDINA COMMON STONE, TAR FILLED; MEDINA COMMON STONE, SAND FILLED, AND BRICK, TAR FILLED

| Size of main, in. | 20 | 18 | 16 | 12 | 10 | 9 | 8 |
|---|---|---|---|---|---|---|---|
| Width of trench for pipe, ft. and in... | 4-5 | 4-3 | 4-1 | 3-7 | 3-5 | 3-4 | 3-3 |
| Width of pavement removed for trench,* ft. and in. | 6-1 | 5-11 | 5-9 | 5-3 | 5-1 | 5-0 | 4-11 |
| Sq. ft. of pavement removed per lineal ft. .............. | 6.08 | 5.91 | 5.75 | 5.25 | 5.08 | 5.00 | 4.91 |
| Opening in pavement for a Variator, ft. and in.... | 10-0 x 5-6 | 9-10 x 5-1½ | 9-8 x 5-0 | 9-4 x 4-11 | 9-2 x 4-10½ | 9-1½ x 4-9½ | 8-11½ x 4-8½ |
| Sq. ft. of pavement removed for Variator .......... ... | 55.0 | 49.9 | 48.3 | 45.9 | 44.7 | 43.5 | 42.2 |
| Opening in pavement for Anchor Special, ft. and in. | 8-7½ x 4-0 | 8-5 x 3-10 | 7-10½ x 3-8½ | 7-8 x 3-6½ | 7-6 x 3-5½ | 7-5 x 3-5 | 7-4 x 3-4½ |
| Sq. ft. of pavement removed for Anchor Special ..... | 34.5 | 32.2 | 29.2 | 27.1 | 25.9 | 25.4 | 24.7 |
| Opening in pavement for a Cross, ft. and in........ | 8-6½ x 5-6½ | 8-3½ x 5-3½ | 8-0½ x 5-0½ | 7-6½ x 4-6½ | 7-4½ x 4-4½ | 7-2½ x 4-2½ | 7-0½ x 4-0½ |
| Sq. ft. of pavement removed for Cross | 47.3 | 43.8 | 40.5 | 34.2 | 32.2 | 30.4 | 28.4 |

*NOTE:—20 in. is added to the width of the trench for loss in toothing the pavement along the edge of the excavation.

good condition. In treating these factors the writer will classify according to the kind of pavement. The reason for this is that the amount of pavement necessary to be removed or relaid for a given size of pipe line varies with the different kinds of pavements. Tar filled pavements require a greater width than cement filled, and sand filled pavements more than tar filled. The amount

of repaving in every case is found to be proportionate to the strength of the pavement in resisting the wear and tear along the edges of the openings that are made.

In removing the pavement only such width of the pavement should be removed as is necessary to allow room for the construction of the trench. These estimated widths are based upon the experience of the underground construction Engineer as to

TABLE 3. PAVEMENT REMOVED FOR MEDINA DRESSED STONE, CEMENT FILLED; BRICK, CEMENT FILLED, AND ASPHALT

| Size of main, in. | 20 | 18 | 16 | 12 | 10 | 9 | 8 |
|---|---|---|---|---|---|---|---|
| Width of trench for pipe, ft. and in... | 4-5 | 4-3 | 4-1 | 3-7 | 3-5 | 3-4 | 3-3 |
| Width of pavement removed for trench, ft. and in. | 4-5 | 4-3 | 4-1 | 3-7 | 3-5 | 3-4 | 3-3 |
| Sq. ft. of pavement removed per lineal foot ....... | 4.42 | 4.25 | 4.08 | 3.58 | 3.41 | 3.33 | 3.25 |
| Opening in pavement for a Variator, ft. and in... | 8-4 x 5-6 | 8-2 x 5-1½ | 8-0 x 5-0 | 7-8 x 4-11 | 7-6 x 4-10½ | 7-5½ x 4-9½ | 7-3½ x 4-8½ |
| Sq. ft. of pavement removed for a Variator ........ | 45.8 | 41.9 | 40.0 | 37.7 | 36.5 | 35.7 | 34.3 |
| Opening in pavement for Anchor Special, ft. and in. | 6-11½ x 4-0 | 6-9 x 3-10 | 6-2½ x 3-8½ | 6-0 x 3-6½ | 5-10 x 3-5½ | 5-9 x 3-5 | 5-8 x 3-4½ |
| Sq. ft. of pavement removed for Anchor Special ..... | 27.8 | 25.8 | 23.0 | 21.2 | 20.2 | 19.7 | 19.1 |
| Opening in pavement for a Cross, ft. and in........ | 6-10½ x 5-6½ | 6-7½ x 5-3½ | 6-4½ x 5-0½ | 5-10½ x 4-6½ | 5-8½ x 4-4½ | 5-6½ x 4-2½ | 5-4½ x 4-0½ |
| Sq. ft. of pavement removed for Cross | 38.1 | 35.0 | 32.2 | 26.7 | 24.9 | 23.3 | 21.7 |

the amount of room needed and the width of pavement to be taken up under usual construction conditions. These figures will vary according to the kind of pavement in question.

It should be the practice in construction work to mark on the surface of the street in advance of the trench gang, the width of pavement that is to be taken up and the figures given later under this subject will correspond to the widths which should be laid out for the job.

The repaving over street openings is in general, done by the Municipal authorities. An exception may be made in the case

of streets where the paving was put down by a contractor under a guarantee for a definite number of years and in this case the repaving done by that Contractor. In either case the cost is paid by the Company for whom the street was opened.

It is invariably found that the pavement is more or less dis-

TABLE 4. SQUARE FEET OF PAVEMENT REPLACED

FOR MEDINA DRESSED STONE, TAR FILLED.

| Size of Main, in. | 20 | 18 | 16 | 12 | 10 | 9 | 8 |
|---|---|---|---|---|---|---|---|
| Lineal ft. of trench | 8.75 | 8.51 | 8.28 | 7.56 | 7.32 | 7.20 | 7.07 |
| Variator | 79.20 | 71.85 | 69.55 | 66.10 | 64.37 | 62.64 | 60.77 |
| Anchor Special | 49.68 | 46.37 | 42.05 | 39.02 | 37.30 | 36.58 | 35.57 |
| Cross | 68.11 | 63.07 | 58.32 | 49.25 | 46.37 | 43.77 | 40.89 |

FOR MEDINA DRESSED STONE, CEMENT FILLED.

| Size of Main, in. | 20 | 18 | 16 | 12 | 10 | 9 | 8 |
|---|---|---|---|---|---|---|---|
| Lineal ft. of trench | 5.75 | 5.52 | 5.30 | 4.65 | 4.43 | 4.33 | 4.22 |
| Variator | 59.54 | 54.47 | 52.0 | 49.01 | 47.45 | 46.41 | 44.59 |
| Anchor Special | 36.14 | 33.54 | 29.90 | 27.56 | 26.26 | 25.61 | 24.83 |
| Cross | 49.53 | 45.50 | 41.86 | 34.71 | 32.37 | 30.29 | 28.21 |

FOR MEDINA COMMON STONE, TAR FILLED.

| Size of Main, in. | 20 | 18 | 16 | 12 | 10 | 9 | 8 |
|---|---|---|---|---|---|---|---|
| Lineal ft. of trench | 8.69 | 8.45 | 8.22 | 7.51 | 7.26 | 7.15 | 7.02 |
| Variator | 78.65 | 71.36 | 69.07 | 65.64 | 63.06 | 62.20 | 60.35 |
| Anchor Special | 44.33 | 46.04 | 41.75 | 38.75 | 37.04 | 36.33 | 35.32 |
| Cross | 67.64 | 62.63 | 57.91 | 48.90 | 46.05 | 43.47 | 40.61 |

FOR MEDINA COMMON STONE, SAND FILLED.

| Size of Main, in. | 20 | 18 | 16 | 12 | 10 | 9 | 8 |
|---|---|---|---|---|---|---|---|
| Lineal ft. of trench | 9.67 | 9.40 | 9.14 | 8.35 | 8.08 | 7.95 | 7.81 |
| Variator | 87.45 | 79.34 | 76.80 | 72.98 | 71.07 | 69.16 | 67.10 |
| Anchor Special | 54.85 | 51.20 | 46.43 | 43.29 | 41.18 | 40.38 | 39.27 |
| Cross | 75.21 | 69.64 | 64.39 | 54.38 | 51.20 | 48.33 | 45.15 |

FOR BRICK, TAR FILLED.

| Size of Main, in. | 20 | 18 | 16 | 12 | 10 | 9 | 8 |
|---|---|---|---|---|---|---|---|
| Lineal ft. of trench | 9.24 | 8.98 | 8.74 | 7.98 | 7.72 | 7.60 | 7.46 |
| Variator | 83.60 | 75.85 | 73.42 | 69.77 | 67.94 | 66.12 | 64.14 |
| Anchor Special | 52.44 | 48.94 | 44.38 | 41.19 | 39.37 | 38.61 | 37.54 |
| Cross | 71.90 | 66.57 | 61.56 | 51.98 | 48.94 | 46.31 | 43.17 |

FOR BRICK, CEMENT FILLED.

| Size of Main, in. | 20 | 18 | 16 | 12 | 10 | 9 | 8 |
|---|---|---|---|---|---|---|---|
| Lineal ft. of trench | 6.14 | 5.91 | 5.67 | 4.97 | 4.84 | 4.63 | 4.52 |
| Variator | 63.66 | 58.24 | 55.60 | 52.40 | 50.73 | 49.62 | 47.68 |
| Anchor Special | 38.64 | 35.86 | 31.97 | 29.47 | 28.08 | 27.38 | 26.55 |
| Cross | 52.96 | 48.65 | 44.76 | 37.11 | 34.61 | 32.39 | 30.16 |

FOR ASPHALT.

| Size of Main, in. | 20 | 18 | 16 | 12 | 10 | 9 | 8 |
|---|---|---|---|---|---|---|---|
| Lineal ft. of trench | 6.01 | 5.78 | 5.55 | 4.87 | 4.64 | 4.53 | 4.42 |
| Variator | 62.29 | 56.98 | 54.40 | 51.27 | 49.64 | 48.55 | 46.65 |
| Anchor Special | 37.81 | 35.09 | 31.28 | 28.83 | 27.47 | 26.79 | 25.97 |
| Cross | 51.82 | 47.60 | 43.79 | 36.31 | 33.86 | 31.69 | 29.51 |

turbed along the edges of the trench as the work of constructing it proceeds. Some of the blocks of stone or brick are loosened or pushed down and a certain amount loses its solid foundation due to caving in of the earth along the excavation.

It is also necessary to tooth the pavement along the edge of the excavation by cutting out blocks or bricks so that the repaving will be properly bonded to the old pavement.

Another factor that increases the amount of the repaving, is the practice of including in the repaving any portions of the pavement adjacent to the excavation which are in poor condition or which show defects such as holes or depressions. If the trench is near the curb or car tracks, it is customary to repave all of the surface from the trench to the curb or car track.

For all of these reasons it invariably follows that on a job of any magnitude the amount of repaving is considerably in excess of the pavement which was taken up to perform the work. The amount of this excess varies as noted before, according to the kind of pavement, being greater for less firm pavements. This has been carefully estimated by the writer from experience and is expressed as a percentage, for each kind of pavement in Table 1.

The succeeding tables (Tables 2 to 4), showing the amounts of paving removed and replaced for the various sizes of mains and various kinds of pavements, follow the actual method that was used by the writer in doing the work on the street.

The amount of pavement replaced is found by adding the necessary percentages as shown in Table 1 to the amount of pavement removed and is shown in Table 4.

The method used in estimating the paving removed and relaid for manholes is the same as that which has been described for the steam main. However, there is no standard size opening that will fill all cases as the size of a manhole will depend upon local conditions. The writer has arrived at an average manhole opening in the street by averaging the sizes of 98 various manholes installed, as follows: 6.93 ft. x 5.54 ft., equivalent to an area of 38.39 sq. ft. The repaving is estimated from the above added percentages with a deduction, however, corresponding to the size of the cast iron cover which is approximately 4.2 sq. ft.

A concrete mat 6 in. thick is found under all such pavements as asphalt, cement-filled dressed Medina stone and about 50 per cent. of cement filled brick. The amount of concrete mat removed and replaced is estimated as having a width equal to the width of trench for pipe.

The amount of trench to be opened up at any one time is variable depending upon local conditions and city permit regulations but can be considered between 100 to 300 ft., assuming one half of the length sheeted ready for the pipe line. In trenches five feet or more in depth use not less than two checkings (6x8 in.) per side and sometimes more, depending upon the depth and local conditions. Sheeting can be of steel or hemlock planking and spaced according to depth and local conditions, loose sandy earth requiring closer sheeting than heavier soil. All ditch sheeting should be thoroughly braced to prevent cave in, or accident to the workmen or the progress of the work.

## DATA

Having reviewed quite extensively the problems involved in the design of a steam distributing system, the writer will now devote the remainder of this paper to some data and costs of actual construction work as experienced under his supervision. In arriving at all costs shown herewith, the writer has used the average method, that is, has used an average job of all jobs installed of the various sizes. These costs have been found to be very conservative for estimating new jobs of any given length under similar conditions. It might be of interest to the reader to know the extent of the mains installed under the writer's service and from which the data shown herewith has been derived:

| | |
|---|---|
| 20 in. mains | 8,500 ft. |
| 18 in. mains | 700 ft. |
| 16 in. mains | 11,000 ft. |
| 12 in. mains | 5,900 ft. |
| 10 in. mains | 1,300 ft. |
| 9 in. mains | 5,400 ft. |
| 8 in. mains | 1,000 ft. |

The sub-surface soil in the territory of this steam distributing system was over 90 per cent. sand of an average firmness.

## TRENCHING

In arriving at an estimate for the cost of this work, the best that can be done is judgment and long experience on the part of the Engineer. However, the writer will present a typical problem as a method of procedure, as well as a table compiled by the same method giving the costs per lineal foot of trenching for the various sizes of mains, and which has been found to be remarkably accurate for estimate work.

**FORM FOR ESTIMATE**

Assuming a job of ... ft. length, size of main .. in., required average depth of trench .. ft.

LABOR.

| | | |
|---|---|---|
| 1 Foreman | $4.50 | per day. |
| 1 Sub-foreman | 2.75 | " " |
| 1 Transitman | 3.00 | " " |
| 1 Rodman | 2.75 | " " |
| 6 Laborers @ $2.50 | 15.00 | " " |
| 50 Laborers @ $2.25 | 112.50 | " " |
| 2 Day Watchmen @ $2.25 | 4.50 | " " |
| 2 Night Watchmen @ $2.50 | 5.00 | " " |
| | $150.00 | " " |

Total labor for .. days to do a job of this size ......
Labor Cost per foot of trench ...

The amount of excavated material to be removed from a job is determined by the displacement of the main, that is, the cubic yards occupied by casing, fitting boxes and manholes.

Excess excavated material to be hauled an average distance of .. miles; this allows about .. loads per day for each wagon.

Assuming excess excavated material to be approximately ... cubic yards this will require:

.. Teams .. days @ $6.00 per day ......

For hauling sheeting, pipe, fittings, etc.

.. Truck .. days @ $6.00 per day ......

.......

or a cartage cost per foot of trench ...

INCIDENTAL MATERIAL.

| | | |
|---|---|---|
| ... pcs. of 2 x 12 in. x 12 ft. hemlock @ $29.00 | ...... | |
| Less salvage of 20 per cent | ...... | |
| | | ...... |
| .. pcs. of 6 x 8 in. x 20 ft. hemlock @ $29.00 | ...... | |
| . pcs. of 2 x 6 in. x 10 ft. hemlock @ 29.00 | .... | |
| | ...... | |
| Less salvage of 35 per cent | ..... | |
| | | ...... |
| ... gal. of kerosene oil @ $0.08½ | | ..... |
| ... pounds of spikes @ $2.25 | | .... |
| .. days' use of city water @ $0.20 | | .... |
| .. days' expense miscellaneous @ $0.50 | | ..... |
| | | ...... |

Incidental material cost per lineal foot of trench of ......

INSPECTION.

1 city inspector .. days @ $5.17 ......

Inspection cost per lineal foot of trench ...

In a similar manner the following table (Table 5) has been compiled from actual jobs installed.

TABLE 5. COST PER LINEAL FOOT OF TRENCH

| Size | Labor | Cartage | Incidental Material | Inspection |
|---|---|---|---|---|
| 20 in. | $4.26 | $0.40 | $0.43 | $0.15 |
| 18 in. | 4.11 | .39 | .43 | .14 |
| 16 in. | 3.54 | .31 | .43 | .12 |
| 12 in. | 2.85 | .24 | .35 | .10 |
| 10 in. | 2.41 | .21 | .35 | .10 |
| 9 in. | 2.29 | .20 | .32 | .10 |

In estimating the material to be used for enclosing fittings, the writer has compiled the Table 6 from actual dimensions of fittings with proper clearances.

TABLE 6. MATERIAL REQUIRED FOR ENCLOSING FITTINGS

| | | | | | | |
|---|---|---|---|---|---|---|
| **VARIATORS** | | | | | | |
| Size of Main, in. | 20 | 18 | 16 | 12 | 10 | 9 |
| No. of brick | 1370 | 1295 | 1210 | 1050 | 975 | 955 |
| Cubic yd of concrete for cover | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.3 |
| Board ft. of 2x6 in. plank | 70 | 68 | 64 | 60 | 58 | 56 |
| Sacks of Cement | 11.5 | 10.5 | 10.0 | 9.0 | 8.5 | 8.0 |
| Tons of stone | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.25 |
| Bales of shavings | 5 | 4½ | 4 | 3 | 2½ | 2½ |
| **ANCHOR SPECIALS** | | | | | | |
| Size of Main, in. | 20 | 18 | 16 | 12 | 10 | 9 |
| No. of brick | 910 | 795 | 675 | 555 | 470 | 445 |
| Cubic yd. of concrete for cover | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 |
| Board ft. of 2x6 in. plank | 42 | 40 | 34 | 32 | 30 | 28 |
| Sacks of cement | 7.5 | 6.5 | 5.5 | 4.5 | 4.0 | 4.0 |
| Tons of stone | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Bales of shavings | 4½ | 4 | 3½ | 2½ | 2 | 2 |
| **CROSS OR TEES** | | | | | | |
| Size of Main, in. | 20 | 18 | 16 | 12 | 10 | 9 |
| No. of brick | 1005 | 883 | 815 | 625 | 540 | 500 |
| Cubic yd. of concrete for cover | 0.4 | 0.4 | 0.3 | 0.3 | 0.3 | 0.2 |
| Board ft. of 2x6 in. plank | 66 | 60 | 56 | 46 | 42 | 39 |
| Sacks of cement | 8.5 | 7.5 | 6.5 | 5.5 | 5.0 | 4.0 |
| Tons of stone | 0.50 | 0.50 | 0.25 | 0.25 | 0.25 | 0.25 |
| Bales of shavings | 3 | 3 | 2½ | 2 | 2 | 2 |
| **ANGLES JOINTS** | | | | | | |
| Size of Main, in. | 20 | 18 | 16 | 12 | 10 | 9 |
| No. of brick | 745 | 620 | 580 | 435 | 365 | 320 |
| Cubic yd. concrete for cover | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 |
| Board ft. of 2x6 in. plank | 40 | 34 | 34 | 28 | 24 | 22 |
| Sacks of cement | 6.0 | 5.0 | 5.0 | 4.0 | 3.0 | 2.5 |
| Tons of stone | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.125 |
| Bales of shavings | 3 | 3 | 2½ | 2 | 2 | 2 |

In the above tables the following proportions were used for laying 1,000 brick (1:4 mixture): 7 sacks cement and 1 cu. yd. sand per 1,000 brick; for laying one cubic yard of concrete (1:

4:6 mixture): 3.8 sacks cement per cu. yd.; 0.56 cu. yds. sand per cu. yd., and 1.05 tons stone per cu. yd. It might be noted that all sand was available on the job, so it is not included in the costs.

The estimating of the cost of material for a manhole is a variable factor as the manhole is dependent upon the local conditions. The writer has investigated the cost of some eighty different manholes that have come under his construction and has arrived at an average cost of $110.00 per manhole. This cost includes the brickwork for the sides, concrete for the bottom and top, old iron tee rails for supports in roof, sewer connections and permits, sewer grates, manhole frame and cover, supervision and incidentals.

### PAVING

In arriving at and compiling the following table on the costs of removing the various kinds of pavement per sq. ft., the writer used results from over 90 per cent. of the jobs done. During the progress of the job six laborers at $2.25 a day and a foreman at $2.75 a day were detailed to remove pavement in advance of the ditch gang. In the case of a large job and especially at the start of a job additional laborers are put on, these laborers' time being accounted to the charge of removing paving and the following costs are remarkably accurate for this class of work. Cement filled pavings were found to cost considerable more than other types of paving due to the cementing together of the blocks as well as the concrete mat beneath.

TABLE 7. LABOR COSTS OF REMOVING VARIOUS KINDS OF PAVING IN CENTS PER SQUARE FOOT

| | |
|---|---|
| Dressed Medina stone, tar filled | 1.3 |
| Dressed Medina stone, cement filled | 5.6 |
| Dressed Medina stone, sand filled | 0.8 |
| Brick, tar filled | 1.1 |
| Brick, cement filled | 5.3 |
| Asphalt | 4.75 |
| Stone or cement walk | 1.7 |

As all of the paving relaid was done by municipal authorities, or by contractors on guaranteed jobs and the actual cost billed the company, the writer took the average of the billed costs for the various kinds of pavement in compiling the table on costs per square foot for relaying pavement. It might be mentioned further that the company's inspector was on the jobs to check up the repaving done and his time was charged in the costs.

TABLE 8. LABOR AND MATERIAL COST OF REPAVING VARIOUS KINDS OF PAVEMENTS IN CENTS PER SQUARE FOOT (USING ALL OLD PAVEMENT AS FAR AS POSSIBLE)

| | |
|---|---|
| Dressed Medina stone, tar filled | 14.05 |
| Dressed Medina stone, cement filled | 35.66 |
| Common Medina stone, tar filled | 9.08 |
| Brick, tar filled | 18.01 |
| Brick, cement filled | 27.96 |
| Asphalt | 23.37 |
| Cement walk | 12.00 |
| Common Medina stone, sand filled | 6.56 |

As mentioned before, under certain kinds of pavements was found a concrete mat 6 in. thick. It was customary for the company to replace this concrete with its own labor and for the municipal authorities to relay the pavement on top of the mat. The cost of the concrete has not been included in the above repaving unit price, so a separate price must be applied to all repaving where this mat is found. This concrete mat was made of 1:3:5 mixture and of the following estimated quantities of material per square foot of mat:

| | |
|---|---|
| Cement | 0.021 bbl. |
| Sand | 0.0096 cu. yd. |
| Stone | 0.0198 tons |

The cost of material per square foot of mat as delivered on the street at point of use was:

| | |
|---|---|
| Cement 0.021 x $1.65 = | $0.0347 |
| Sand 0.0096 x 1.00 = | 0.0096 |
| Stone 0.0198 x $1.60 = | 0.0317 |
| Total | $0.0760 |

The cost of labor for placing the concrete mat, mixing with a steam concrete mixer and distributing in buggies, placing and tamping by hand, was estimated on an average output of 20 cu. yd. per day equal to 1,080 sq. ft. of mat in place, with the following gang:

| | | |
|---|---|---|
| 1 Foreman @ | $2.75 | per day |
| 1 Engineer @ | 2.75 | " " |
| 1 Fireman @ | 2.50 | " " |
| 14 Laborers @ $2.25 | 31.50 | " " |
| Total | $39.50 | |

or a labor cost per square foot of mat of $0.036. A certain amount of incidental material such as coke for mixer, cylinder oil, lubri-

cating oils, kerosene, waste and water was charged to the laying of concrete mat and was found to be an average expense of $1.50 a day or an incidental charge per square foot of mat of $0.0014.

There was no charge for cartage on the cement and stone as those were delivered free at the price quoted. However, it was necessary to allow for the cost of bringing the concrete mixer, buggies, and other tools to the job, moving the same from place to place and finally returning same to yard. It was found that this approximated very closely to a team and driver's time for a half day every day that the gang was working, namely, $3.00 a day, or a charge per square foot of mat of $0.0028. It was also necessary to have a city inspector for every day working and his charge accounted likewise, namely, $5.17, or a charge per square foot of mat of $0.0048.

Summing these charges up gives us the cost of concrete mat laid per square foot, and which must be added to the repaving unit price where found:

| | | |
|---|---|---|
| Material | $0.0760 | per sq. ft. |
| Labor | 0.0360 | " " " |
| Incidentals | 0.0014 | " " " |
| Cartage | 0.0028 | " " " |
| Inspection | 0.0048 | " " " |
| Total | $0.1210 | |

In conclusion the writer would like to draw a comparison with some costs that Prof. Verner compiled in his paper in the January, 1916, issue of the Journal, entitled: Cost of Removing and Replacing Pavements* as shown in Table 9.

TABLE 9. COMPARISON OF COSTS FOR REMOVING PAVEMENTS

| PROF. VERNER | | AUTHOR | |
|---|---|---|---|
| Asphalt on concrete | 0.0467 | Asphalt on concrete | 0.0475 |
| Brick on concrete | 0.0452 | Brick, cement filled | 0.053 |
| Cobblestone on sand | 0.0145 | Medina Stone, tar filled | 0.013 |
| Granite block on concrete | 0.0512 | Medina Stone, cement filled | 0.056 |
| Cedar block on concrete | 0.0338 | Medina Stone, sand filled | 0.008 |
| Cedar block on sand | 0.0156 | Brick, tar filled | 0.011 |
| Creosoted block on concrete | 0.0359 | Cement walk | 0.017 |

It will be noted that the first four kinds in both estimates run about the same, as these are similar types of paving.

* See page 121 of this Volume.

TABLE 10. COMPARISON OF COSTS OF RELAYING PAVING IN CENTS PER SQUARE FOOT

| PROF. VERNER | | AUTHOR | |
|---|---|---|---|
| Asphalt on concrete | 0.324 | Asphalt | 0.347 |
| Brick on concrete | 0.289 | Brick, cement filled | 0.393 |
| Granite Block on concrete | 0.323 | Medina Stone, cement filled | 0.470 |
| Cobblestone on sand | 0.084 | Medina Stone, tar filled | 0.091 |
| Cedar block on concrete | 0.287 | Dressed Med. Stone, tar filled | 0.141 |
| Cedar block on sand | 0.129 | Brick, tar filled | 0.180 |
| Creosoted block on concrete | 0.323 | Common Med. Stone, sand filled | 0.066 |

## DISCUSSION

R. J. MAYER: I would like to ask what provision is made in this trench work for foundations to carry the load of the piping and the entire construction.

H. M. HART: With reference to the notes on the cost of laying pipe, I would like to know at what rates the labor was employed to arrive at these quantities, because that is a variable quantity.

R. J. MAYER: What is the life of the wood casing that the writer specifies in his paper?

W. F. VERNER: This paper is of special interest to me on account of the comparison between these figures and those given in the paper submitted by me in the January, 1916, issue of the Journal.* The question comes up in my mind as to just how much overhead is included in these figures. As far as I can learn from the paper, the cost of repaving includes the city's overhead; that is, the city does the repaving and naturally they would bill the company an amount to cover the cost and their overhead.

I note also that the city inspection charge is included. If that is deducted it would make the figures more comparable to mine, as my figures included no city inspections.

The question comes up as to how to use these figures in finding the cost per foot of trench. I would like to ask Mr. Valentine whether it was the policy of the company to open up the entire trench; I mean, if he were running a block, to open up the entire block, or merely take up so many feet and leave a space which was not cut.

THE AUTHOR: In answer to Mr. Mayer's inquiry regarding the provision for foundation, will say that this all depends on the size of the pipe. If it is a very large pipe, say from 16 to 20 in.

* See page 121 of this Volume.

inclusive, I followed the practice of putting 4 x 6 in. sleepers spaced from 10 to 15 ft. apart under the casing; that is, after the grade was established we would lay these sleepers level with the grade and tamp them down solid, and then come along and lay the wood casing on top of same. This gave a very steady foundation for the pipe, and caused the load to be equally distributed between the anchor points.

The labor price for laying pipe was based on union scale in Cleveland. That is, union fitters were the only labor we could get. I have not been in this work for over a year now, but we had to pay as I remember, the steam fitter $5.60 a day for nine hours, and the helper, $2.80. Those were the union scales at that time.

In regard to the life of the wood casing, that is entirely dependent upon local soil conditions. I have taken up wood casings that had been installed for ten years and found them to be in practically the same condition as when installed. In other cases, where there was moisture or quicksand, I have found the casing badly deteriorated, due to heat in the pipe together with the water, which had charred it, so that its life was absolutely destroyed, and it had hardly been in three years. This goes to show that the life of the wood casing is all-dependent on local soil conditions.

In regard to the life of the pipe, I have taken up mains that had only been installed three years, where electrolysis had come in contact with it, and its usefulness was entirely gone. In large cities you have everything imaginable to contend with.

In regard to the opening up of the street, or the limiting of the opening up of the street, the city regulations in Cleveland would not permit us to open up more than 300 ft. at one time. In that way we were obliged to open up about 150 ft., put on a large gang and quickly move the earth so that the steam fitters could start placing the pipe, and these were followed by a filling-in gang, who filled and tamped the trench so that in very short time we were ready to open up 300 ft. more. It had to be a continuous movement from the time it was started to the time it was finished.

In reply to the question asked in regard to overhead charges, these were taken into account,—I have not entered them here in this paper, but as near as I can remember we added to the average labor cost of this work 0.3 per cent. for accounting, 2.9 per cent. for construction superintendence and 3.3 per cent. for tools. Of course, there were some other overhead charges—what those were I cannot remember, but they are included in these estimates.

No. 425

# HEATING A CONSERVATORY AND GREEN-HOUSE

By J. D. Hoffman, Lincoln, Nebr.

**Member**

IN the spring of 1911 the author was asked to lay out the heating system for a conservatory and greenhouse building, then in the process of erection. As the conditions that had to be met were somewhat unusual and since it has now had five seasons of suc-

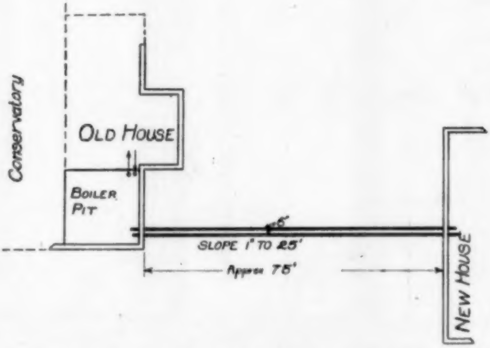


FIG. 1. CONDUIT CONNECTIONS TO NEW CONSERVATORY.

cessful service, a description of the heating system may be of interest to the members of the Society.

Fig. 1 shows the location of the new conservatory relative to the old one, which had been fitted up in 1909, and from which building all the plant development in the new building was to be directed. Because of the close connection between the work

Presented at the Semi-Annual Meeting of The American Society of Heating and Ventilating Engineers, Detroit, Mich., July, 1916.

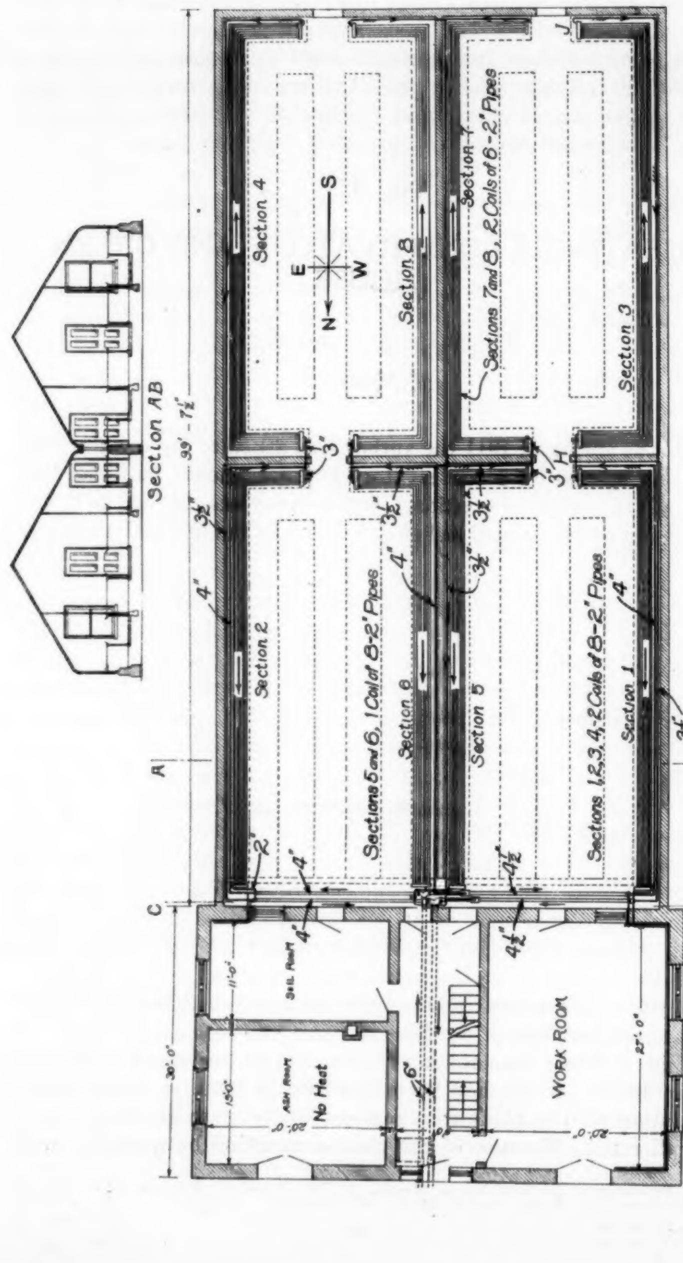


FIG. 2. GROUND FLOOR PLAN OF THE NEW CONSERVATORY.

carried on in the two buildings and to simplify operating conditions, the new heating plant was connected with the heating plant of the old conservatory. The latter was housed in a one and one-half-story wing on the south side of a three-story building devoted to agricultural experiment work. The heating system in this plant was hot water, open tank type, with the radiators and coils all connected on the downward-flow principle, i.e., all the hot water from the heater was directed first to the highest point of the circulating system and then subdivided to the

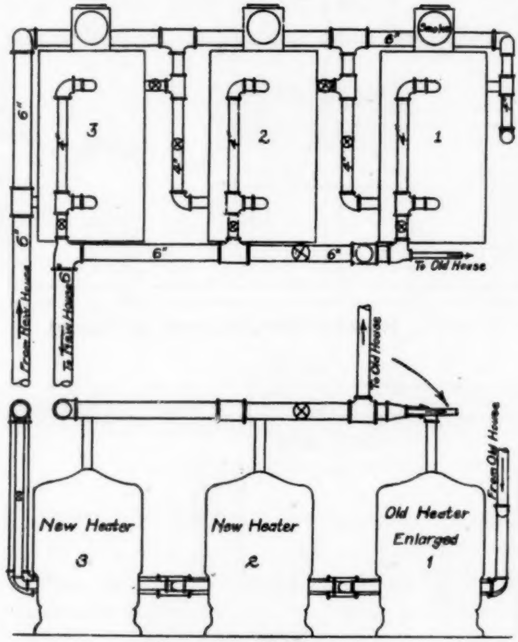


FIG. 3. REVISED HEATER LAYOUT IN OLD CONSERVATORY.

various coils and radiators on the return flow. The old conservatory rooms were badly cut up and the heating connections were rather complicated, but this system was then giving satisfaction, and no changes were contemplated in that part.

The problem was to connect the new heating system of 5,000 sq. ft., by conduit to the old heating system having 1,200 sq. ft. of radiation, increase the heater plant from 1,850 to 8,000 sq. ft. rated capacity, reconstruct the system of mains at the heaters

and serve both systems from the same plant without interfering with the operation of the old plant.

The new conservatory consisted of a two-story brick front building with two 25 x 100 ft. greenhouse extensions. The second floor radiation in the conservatory was to be planned but not installed with the heating system; consequently the new system would operate for the present on the expansion tank in the old

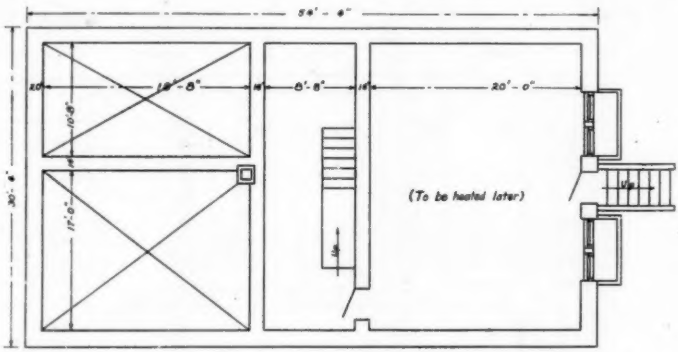


FIG. 4. PLAN OF CONSERVATORY BASEMENT.

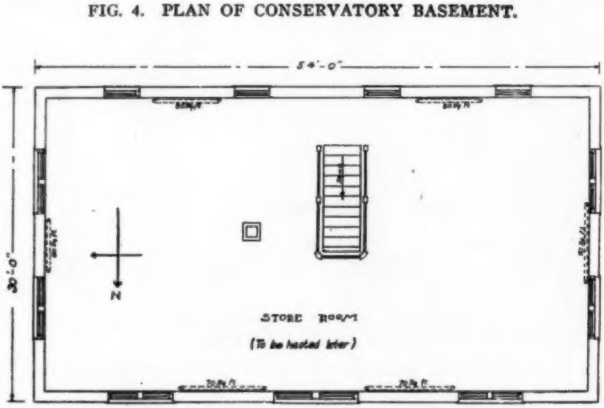


FIG. 5. PLAN OF SECOND FLOOR OF CONSERVATORY.

system. At a later date, if the second floor heating were installed, this tank would necessarily be raised to a higher position or moved to the new plant since the new elevation would be above that of the present tank.

The feature that caused the greatest concern in the union of the two systems was the fact that the circulating water had to

be carried by conduit a distance of 100 ft. with a rise of less than 6 in. and then extended beyond this point a distance of 100 ft. through mains and coils, as shown in Fig. 2, with a rise of not to exceed 3 ft. The heaters had to be set in the present pit. This was sufficiently low to give a fair depth of conduit but permitted very little pitch to the mains. The heating plant was installed according to the plans without change. When completed every coil and radiator in each of the two systems did its work satisfactorily from the first firing and has been equal to the most extreme weather conditions experienced.

The calculations for the various rooms for an inside tempera-

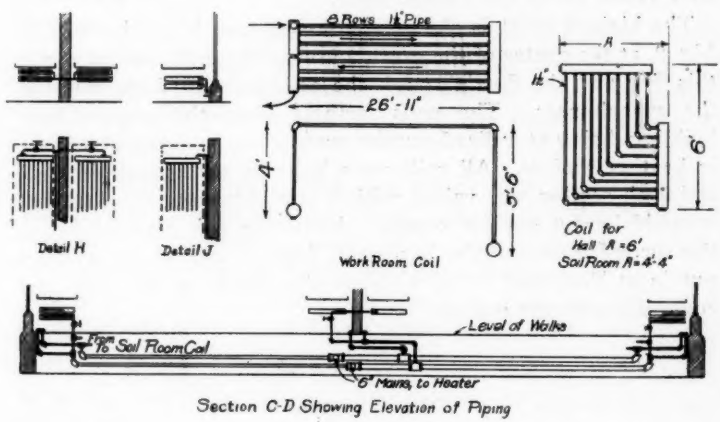


FIG. 6. DETAILS OF COILS AND CONNECTIONS IN GREENHOUSE.

ture of 70 deg., an outside temperature of –10 deg. and an average water temperature at the coils of 165 deg. gave as follows:

| Room | Heat loss B.t.u. | Radiation Approx., sq. ft. | Coils |
|---|---|---|---|
| Work room | 23800 | 140 | 280 lin. ft. 1½ in. pipe |
| Soil room | 8500 | 50 | 100 lin. ft. 1½ in. pipe |
| Hall | 12750 | 75 | 150 lin. ft. 1½ in. pipe |
| North greenhouse (each) | 149600 | 1760 | 5000 lin. ft. 2 in. pipe |
| South greenhouse (each) | 168300 | 1980 | 375 lin. ft. 3½ in. pipe |
| | | | 175 lin. ft. 4 in. pipe |
| Store room (later) | 66300 | 390 | |
| Basement (later) | | 150 | |
| Total | | 4545 sq. ft. | |
| Mains and branches | | 500 | |
| | | 5045 sq. ft. | |

Two type W-25-8 Ideal boilers, of 3,050 sq. ft. capacity each, were installed for the new plant. This was 20 per cent. above requirements and served as a safety factor. Provision was also made to enlarge the old boiler by three sections and make the three heating units equal. The two new units were connected to the old one, as shown in Fig. 3, in such a way that any heater could be used on either or both systems, as desired. The 66-gal. expansion tank was replaced by a 100-gal. tank. The system of mains was arranged to have a uniform rise from the heaters to the ends of the cross trench at the entrance of the greenhouses. From these two branch mains, risers and leads were taken off to the various coils.

The highest point in the greenhouse system is on the line H, Fig. 2, at the center of the greenhouses. The coils are fed along this line and the flow through the coils is toward the ends of the greenhouses. The coils farthest from the conservatory building, being at a disadvantage, were given a slight advantage in heating surface. All coils were built up with manifold ends and each section was valved with a straightaway valve, so that it could be cut out for repairs. Radiation was planned for in the second floor and the basement, Figs. 4 and 5, but was not put in at that time. Fig. 6 shows the details of the coils and connections to the mains.

## DISCUSSION

J. J. BLACKMORE: I would suggest that Professor Hoffman gather and tabulate the costs of the operation of this plant. This paper was solicited from Prof. Hoffman, largely with the idea of getting a line on the cost of operation for greenhouses. Prof. Hoffman seems to have overlooked that part of the request. I think it would make a very good addendum to the discussion if he could give us that data.

E. A. MAY: There is one question in connection with the paper that seems to me worthy of thought, and that is the statement with reference to the boiler rated capacity, or the rated capacity of the boilers used. It has been the custom in speaking of the ratings of boilers to speak of the manufacturer's rating. Now, undoubtedly in Nebraska they are using soft coal with those boilers, and the manufacturer has no rated capacity for soft coil; there is no published rated capacity for soft coal. Therefore, in connection

with the paper, the kind of coal that is being used ought to be stated so that those who are reading can make their relative comparisons as to the boiler capacity which is actually being used.

H. M. HART: That is a good point. In rating boilers, anybody knows that we have to take into consideration the kind of fuel that we are going to use.

E. A. MAY: It is misleading in this respect, that Prof. Hoffman speaks of 20 per cent. reserve, while, as a matter of fact, with the kind of coal he is using, and based on the conditions of the load, he may be running the boilers at their full rated capacity with that kind of fuel.

FRANK K. CHEW: Would it be the idea in this instance with the kind of coal which you have in mind, that these boilers could carry at their rated capacity with hard coal, or would the kind of coal being used there make it impossible for them to come up to their full rating?

E. A. MAY: Evidently they are doing the work satisfactorily, but the point I made was that Prof. Hoffman says that the boiler capacity is 20 per cent. in excess of the load. Conditions may be such that to establish that load, the boilers would be run at such a rate of combustion with soft coal that at a rating for soft coal it would be 100 per cent., and there would be no surplus capacity.

FRANK K. CHEW: The question is to find out whether when a boiler has a hard coal rating, and it can use soft coal to advantage, it will develop a higher capacity, or fall off some. Of course, that is another question entirely from this.

E. A. MAY: If ever I establish a condition whereby I can burn 20 lb. of hard coal, and my conditions are such that with the heat value of the soft coal, I would be compelled to burn 30 lb. of soft coal, my conditions of chimney installation might not be such as to enable me to burn 30 lb. of soft coal; and therefore the rating of the boiler itself must be dependent on its chimney connection and the conditions of installation.

J. J. BLACKMORE: Mr. May's point is well taken, but it might be made a little clearer. It should be noted that in anthracite coal we frequently get values as high as 15,000 B.t.u. per pound, whereas in a great deal of soft coal it falls as low or lower than 9,000. It is also possible that there is not much difference between a good grade of soft coal, and an ordinary grade of hard coal, or anthracite.

THE AUTHOR (written): The heating plant here described is located in the United States Experiment Station, Purdue University. The plans were made just before, and the installation was made just after I left to take up work in my present position at the University of Nebraska.

At the time the Secretary invited me to prepare this paper, a thorough test of the plant had been planned by Prof. Veal of Purdue University and the test data were to be used in the paper. For reasons not known to me the test was not made, and to fulfill my promise, the paper was presented in part, in the hope that the test data would be available later.

Concerning the boiler rating, selection was made on the basis of a good grade of bituminous coal averaging 13,000 B.t.u. per pound.

No. 426

# EFFECT OF THE A. S. M. E. BOILER CODE ON HEATING BOILERS

By C. W. Obert, New York

Member

THAT the Code recently formulated by the Boiler Code Committee of The American Society of Mechanical Engineers cannot fail to have a beneficial effect upon the heating boiler industry in general wherever it is introduced, is the writer's firm conviction and confident prediction. The advantages which it offers to both manufacturers, users and to the public in general have not begun to be appreciated. It has not as yet been operative as a construction code in the five states and three cities in which it has been established, for a sufficient length of time to conclusively demonstrate what may be accomplished, yet there are growing indications that the obstacles which at first threatened its success, have not taken form.

There was, particularly in the early stages of the Boiler Code Committee's work, some apprehension as to the actual purpose of the Code and as to possible injurious results to the status of low-pressure heating boiler service in general. The Committee was, in fact, at one time, confronted with an opposition from the heating industry that promised to become serious. But the fact that the work was finally completed in a form both commendable from a technical standpoint and satisfactory from a practical standpoint to the trade in general, is highly creditable to the representatives of the heating boiler industry who worked with the Boiler Code Committee in the formulation of the Code.

The movement instituted by the Boiler Code Committee, which was based on "safety first" considerations and humanitarian motives, was necessary to meet the demands of the times, and it

Presented at the Semi-Annual Meeting of The American Society of Heating and Ventilating Engineers, Detroit, Mich., July, 1916.

was proposed as an effort worthy of the attention of the great national body of mechanical engineers which alone could furnish the unquestionable talent required to properly establish such a standard. It is one movement that has been signalized by its purpose to incorporate the highest engineering standards and safety ideals entirely regardless of commercial considerations. Yet withal the work has differed from the custom of many of the reform movements in that there has been a noticeable absence of destructive effects to established industries or interests; the effort of the Committee has throughout been to work along constructive lines, holding fixedly throughout to the original purpose of maximum protection to life and property.

Completion of the work of formulating the Code was accomplished largely by cooperation with all interested organizations which served most effectually to break down the barriers of opposition from all directions. After the preliminary reports of the Boiler Code Committee were prepared and submitted to engineers of all classes and in all lines, the cooperation of all technical schools, insurance companies, inspectors, and manufacturing companies interested was invited, and, still later, the further cooperation of all engineering organizations, following which numerous hearings and conferences were held in order to determine if there might be just cause for any opposition to the Boiler Code movement. Probably no feature of the work of the Boiler Code Committee contributed more toward the final success of the Code than this effort toward cooperation and the subsequent adjustment of such details of the rules of the Code as might prove injurious to any of the allied interests.

There were, at the time the formulation of the Boiler Code was commenced, 10 states and 19 municipalities that had in force laws for the compulsory inspection of steam boilers; these laws all differed from one another materially and there was a woeful lack of uniformity. It was foreseen that if some attempt were not made to unify practice throughout the country, the extension of still more new laws in other localities might result which would add to the standards that were at variance with each other and add further to the hardship that was being imposed upon boiler builders and users. Hence the proposal of a Code that might be suitable for recommendation to states, municipalities, boiler inspection companies, and to the engineering profession at large as a model for boiler construction.

There was need for the Code from the standpoint of safety also. Disastrous boiler explosions have occurred in all classes

of boilers and the importance of the prevention of such accidents cannot be too highly emphasized. Such disasters can only be avoided by constructing boilers and their appurtenances in as nearly perfect a manner as possible.

The development of the A. S. M. E. Code involved the most careful and painstaking work. Following the preparation of the first preliminary draft of rules and specifications, the Committee re-wrote the entire Code into the form of preliminary report which was sent out in March 1914, with an accompanying letter inviting criticisms from all the recipients, approximately 1800. This report was issued particularly to engineers known to have special knowledge of the manufacture and operation of steam boilers and other pressure vessels. At the Spring Meeting of the Am. Soc. M. E. in St. Paul, June 16-19, 1914, where the first discussion in open meeting was conducted by the Committee, it was decided to hold a public hearing in September, for all interests affected. This hearing, which was held in the Engineering Societies Building in New York, September 14-16, 1914, was one of the largest and most representative gatherings ever held in the Building. At that meeting there were representatives from many of the greatest industrial and professional interests of the United States, including the steel manufacturers, the railroads, the water tube boiler manufacturers, the tubular boiler makers, heating boiler manufacturers, the agricultural boiler makers, and the heating and ventilating engineers. The hearing developed into one of the most important movements ever undertaken for the protection of human life and property.

At the end of this hearing the steel makers and the representatives of the National Association of Tubular Boiler Manufacturers agreed with the Boiler Code Committee upon the grades of boiler material to be used. A week or so later, as their contribution, the tube manufacturers submitted a uniform specification for boiler tubes. Then practically all of the safety valve manufacturers similarly agreed upon a uniform specification for safety valves, this being the first time in their history that they had come together in consultation as to what would be the best for public safety. While these great bodies of qualified and interested men were agreeing on standards, the railroad interests of the country were hard at work preparing a most helpful criticism of this preliminary report, which helped more towards the bringing of these standards to actual completion than any other which had come before the Committee.

The heating boiler interests were represented by the appoint-

ment of a representative on the Advisory Committee. Two other representatives were appointed to represent particular types of heating boilers. The Advisory Committee, which consisted of eighteen members in all, was called in to assist the original Committee in the completion of the work, and the work of the Advisory Committee proved of great assistance in establishing the Rules. The relation of heating practice in general and the requirements for power boilers was given most careful consideration, and in view of the special requirements for heating boilers a section was prepared under the heading, "Boilers Used Exclusively for Low Pressure Steam and Hot Water Supply."

The original Committee was as follows:

| | |
|---|---|
| JOHN A. STEVENS, *Chairman* | CHAS. L. HUSTON |
| WM. H. BOEHM | EDWARD F. MILLER |
| ROLLA C. CARPENTER | H. C. MEINHOLTZ* |
| RICHARD HAMMOND | E. D. MEIER* |

*Deceased.

The Advisory Committee was as follows:

F. H. CLARK, Railroad Sub-Committee, The American Society of Mechanical Engineers.

F. W. DEAN, Consulting Engineers.

THOS. E. DURBAN, Boiler Manufacturers' Association, Uniform Specifications Committee, for all types of boilers.

CARL FERRARI, National Tubular Boiler Manufacturers' Association.

ELBERT C. FISHER, Scotch marine and other types of boilers.

ARTHUR M. GREENE, JR., Engineering Education.

CHAS. E. GORTON, Steel heating boilers.

A. L. HUMPHREY, Railroad Sub-Committee, The American Society of Mechanical Engineers.

D. S. JACOBUS, Water-tube boilers.

S. F. JETER, Boiler insurance.

WM. F. KIESEL, JR., Railroad Sub-Committee, The American Society of Mechanical Engineers.

W. F. MACGREGOR, National Association of Thresher Manufacturers.

M. F. MOORE, Steel heating boilers.

I. E. MOULTROP, Boiler users.

RICHARD D. REED, National Boiler & Radiator Manufacturers' Association.

H. G. SCOTT, Boiler users.

H. H. VAUGHAN, Railroad Sub-Committee, The American Society of Mechanical Engineers.

C. W. OBERT, Secretary to the Committee.

The original Committee and the Advisory Committee were later constituted as the Boiler Code Committee which now consists of all the above names with the exception of those deceased.

A separate section for the rules covering the heating class was established and the rules were so adjusted as to establish a line

of demarcation between the power and heating class of boilers. This arrangement gave ample opportunity for adequate treatment of the special conditions embraced in heating boiler construction and installation and gives thus the opportunity for preventing confusion between the two classes. It gives the opportunity for definitely stating the conditions under which the rules for power boilers shall apply and, conversely, the conditions under which the rules for heating boilers shall apply. In this section, the requirements for maximum allowable working pressures and factor of safety are clearly stated, and all other important details of construction and installation, such as boiler joints, wash-out holes, boiler openings, safety valves, steam and water gages, fittings and appliances, methods of setting, hydrostatic tests, and stamping, are therein very clearly defined in contradistinction to the corresponding requirements for power boilers.

This arrangement of the rules which was largely the result of the suggestions offered by the representatives of the heating boiler interests, will, it is thought, prove effective in preventing, in localities where the Code becomes operative, such disadvantages and hardships as have been found under the original Massachusetts Code and elsewhere. This separation of the two classes will in itself clearly establish before those in charge of the enforcement of these rules, such a distinction, that none of the more rigorous requirements for power boilers may be brought to bear upon the heating boiler class with their possible hardships.

In answer to the occasionally expressed opinion that the Boiler Code as it applies to low-pressure boilers will work a hardship on the manufacturers of heating boilers, it can only be stated that the desire of the Committee was to make it necessary that nothing but safe boilers should be built in the future and all others eliminated. Every precaution was taken by the Committee to be certain that no impossible requirements were imposed and that boilers could be built to these requirements without difficulty from the manufacturer's standpoint. When the feasibility of this was established, no hesitancy was felt by the Committee in recommending a standard in this form. It is felt by the Committee that there has been no rule established that is likely to impose a hardship or work to the disadvantage of any manufacturer who is prepared to build safe boilers. If any rule can be shown to impose a hardship in any way, the Committee desires to be informed of the particulars in order that the condition may be alleviated.

In one very important particular, this final arrangement of the A. S. M. E. Code is advantageous to the low pressure boiler class, namely, in that no rules are imposed on old boilers or boiler installations, or those that are *now* in use. Whereas certain requirements are imposed for old power boiler installations, nothing of the kind is advocated in the Code for the low pressure boilers. This alleviation is a preventative measure, as while it is obvious that an element of danger may exist in the older boiler installations, criticism from the general public is avoided by withholding from this field.

As the Code is promulgated in various parts of the country and introduced into the various states, questions are arising as to the application or meaning of the various rules, and to render interpretations in such inquiries the Boiler Code Committee has been continued to make such revisions as may be found desirable in the rules and to modify them as the state of the art advances.

A resolution was passed by the Council of the Society empowering the Committee to make rulings where inquiries are made respecting constructions not covered by the Code and to interpret any parts of the Code. The various inquiries have been given careful consideration by the Committee, each being given a case number under which it is filed in the records of the Committee, which are preserved at the office of the Society.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed on at a regular meeting of the Committee. This interpretation is submitted to the Council for approval, after which it is issued to the party making the inquiry and later published in The Journal of The American Society of Mechanical Engineers, in order that any one interested may readily secure the latest information concerning the interpretations.

Since the first meeting for issuing interpretations, which was held in Buffalo at the time of the Spring (1915) meeting of the American Society of Mechanical Engineers, three additional meetings were held by the Committee in 1915, and monthly meetings have been held so far in 1916. Fifty-eight inquiries have been considered. Of these, interpretations have been given and published for all but two, which are still in the hands of the Committee.

## DISCUSSION

J. D. CASSELL: The Pennsylvania State Legislature has adopted the A. S. M. E. Boiler Code in its entirety, which if enforced will interfere very materially with the method of heating used in the schools of Philadelphia. For the past thirty years we have used cast iron boilers of various makes, operating same at 30 lb. pressure, for the purpose of supplying engines to propel fan blowers, the exhaust steam being used in the air heater sections, and the condensation returned by pump to boilers. The full 30 lb. steam pressure is carried on the direct radiators, condensation returned by gravity to boilers. This has been a very satisfactory and economical arrangement, as very little of the exhaust steam was wasted to the atmosphere, in fact only for a few days in the late spring or early fall.

If as we understand the Code, 15 lb. is the maximum steam pressure permissible to be carried on boilers of cast iron construction we will be compelled to give up the use of cast iron boilers in connection with our plenum system work, as the size of engine that would be required at the lower steam pressure would be prohibitive.

In talking this matter over with one of the members of the Commission the suggestion was made to substitute an electric motor for the engine drive, but with the prevailing prices for electric current in our city the cost per day to operate one of our average sized plants would approximate $5.50, which is a further incentive in our endeavor to have the maximum allowable steam pressure of cast iron sectional boilers increased to at least 30 lb.

If other heating engineers use the same methods as we, I hope they will join in a movement for this increased pressure. We, however, will take the matter up with our State Industrial Board, as the law reads, "The following safety standards have been adopted by the Industrial Board, subject to the provision of the law, which provides that persons affected may petition the Board for changes in the regulations. Upon the receipt of such petition, it will be reviewed by the Board and if considered necessary a public hearing will be called in regard thereto." I suppose it would then go back to the Boiler Code Committee of the American Society of Mechanical Engineers.

I think the subject is worthy of consideration, as my experience is that cast iron boilers are just as economical in the use of fuel, and will last longer under similar conditions than wrought iron or steel boilers. Furthermore, as most cast iron boilers are of the internal fire box construction, there is an annual saving of at least

3 per cent. in fire lining repair bills, over the usual brick-set return tubular and water tube boilers.

I am indirectly informed that the reason for lowering the allowable steam pressure of cast iron boilers to 15 lb., was not that the boiler would be considered unsafe at any higher pressure, but rather to prevent the cast iron boiler being used to supply steam to engines, pumps or other vessels exhausting into the atmosphere, which would necessitate a constant supply of fresh water to the boiler, with its attendant dirt and scale forming properties, which, in turn, would stop up the small water passages of the boiler, and as these passages cannot be inspected or cleaned, the cast iron boiler must not be used for other than low pressure gravity return work.

We have in use and have had since 1897, over 150 boilers of various kinds of cast iron construction, operating under 30 to 35 lb. steam pressure. During that period many sections have cracked with no further injury or damage to life or property.

During the past winter we had a section crack in one of these boilers that had been in use 19 years. We simply cut the connection nipples out, plugged the openings, left the cracked section remain in place, and operated the boiler for three months. Last week we removed the cracked section. I had it broken up, and did not find over a 1/32 in. of rust or scale, and therefore feel justified in petitioning our State Industrial Board, or if it interests other engineers, the Boiler Code Committee to change the code, permitting at least 30 lb. steam pressure on boilers of proper cast iron construction and used as mentioned.

E. A. MAY: It is only fair to say to Mr. Cassell that possibly the boiler and radiator manufacturers themselves were in a measure responsible, and not the Boiler Code Committee. I had the pleasure of being the Chairman of the Committee of the National Association of Boiler and Radiator Manufacturers who appeared in September before the Committee of the American Society of Mechanical Engineers. The question of the pressures of steam boilers came up, and inasmuch as the majority of heating jobs had been assumed to be under 15 lb. no objection was made by the boiler manufacturers to the Massachusetts limit of 25 lb. In Ohio they set the limit at 15 lb. on a steam boiler without any discussion whatsoever.

However, there was a discussion on the pressure in relation to hot water jobs. I think they now allow a uniform pressure of 30 lb. or higher pressure, provided a test pressure is made at the factory two and a half times the proposed working pressure. I presume that with proper presentation, there would be a special

ruling allowed for higher pressures on the steam boilers. As I say, I think it is only fair to the Mechanical Engineers to say that they themselves were not really responsible. It was overlooked by the manufacturers of cast iron boilers, and the thing practically went by default.

The National Association now has a representative on the Boiler Code Committee in the person of Mr. R. D. Reed of the H. B. Smith Company, who living near New York, was available for committee meetings. I think that proper presentation of the question would bring the proper results.

JOHN C. MCCABE[1]: I am very much interested in the discussion relating to the A. S. M. E. Boiler Code. I have been connected with the boiler inspection work in this City here for the past eight years, and possibly in an indirect way have contributed slightly to the promotion of uniformity in this direction.

The necessity for a uniform code is well known to everybody having anything whatever to do with steam boilers. In the City of Detroit, we have had boiler inspection for about thirty-five years, and during that period up to about 1910, there was absolutely nothing relating to any specifications. Any man might send any kind of a boiler to Detroit, built in any kind of a way, and to carry practically any pressure he saw fit. I went into the office in 1908, and had the pleasure of having a multiplicity of foes for about two years before I could induce the Common Council to adopt the Massachusetts Code. In fact, some people charged me with everything except murder in the course of the fight. Eventually, of course, the code was adopted, and I am pleased to say at the present time that my office has practically no trouble with the boiler manufacturers and that we are accepting boilers built under the A. S. M. E. Boiler Code, and will shortly adopt that Code as the regulation for the city.

In regard to the contention of the gentleman for heating boilers with lap joints, I think experience has demonstrated that a man with a bad reputation generally has a hard time getting along. The lap joint boiler, of course, may have a rather large factor of safety using a low pressure, but at the same time, being a large vessel, it is not a very desirable thing to use for high pressures. I would say in relation to the trouble the gentleman has about driving an engine, that I think it would be much more desirable for him to get a small boiler that would be suitable for his purposes, and use such pressure on it as may be necessary for the desired work, using the

[1]Chief Boiler Inspector, City of Detroit.

exhaust for heating rather than bring about a dangerous condition by using a steam boiler that would be detrimental to public safety.

I find here in the City of Detroit, that we have considerable trouble in keeping track of boilers. You first must remember that all these regulations are to be construed as on a reasonable basis. In other words, our Corporation Counsel has told me that as a matter of law, we could not enforce the use of a butt jointed boiler, nor could we compel the use of boilers with drilled holes. These are facts. The burden of proof is on the inspection office to show that a particular boiler is not a safe boiler. That being true in law, I accepted it as such. It shows that in dealing with the boiler question, we must pursue reasonable methods. Safety in use of steam boilers is dependent on education rather than on enforcement. In fact, I find occasionally that we get a case that we want to see a strict compliance in, but somebody has seen the powers above before we have, and it is a rather difficult matter to straighten out.

I firmly believe that the A. S. M. E. Boiler Code is quite a reasonable one, and some sacrifice must be made, and the engineer ought to figure the thing from an engineering viewpoint rather than take his own particular case as a basis for the course taken. I can readily see from my own experience that the Code Committee must have done a great amount of work if they evolved a Code which was acceptable to all who came under it.

E. F. GLORE: I think the matter of the Code is probably one of the most important subjects that has been taken up for some time in our line. I would recommend that all those who have not read the Code, whether directly interested or not, but who are in the industry, should make it their business to get a copy and digest it. I heard a great deal of it and the discussions in the various bodies before we really got down to an analysis of what it meant. After having learned something about it, I realized that it was perhaps the best thing that has ever come into our industry.

THE AUTHOR: In answer to Mr. Cassell and Mr. May, I will say that the adoption of 15 lb. as the limit of pressure for heating boilers was given, in the early stages of the Boiler Code Committee's work, very careful consideration. At the very beginning of the work, back in 1913, when the committee was first appointed and I was acting as secretary to the committee to carry on the investigative work, we made it our business to learn what Ohio and Massachusetts had done in their codes of boiler rules and we analyzed the results. At that time the Massachusetts board had had a code in effect for about five or six years; and Ohio had had

their code in effect about two years. It was the Committee's effort to find out what results they had had with these various rules under practical application, and see if they could take advantage of any of the mistakes of those two codes.

The 15 lb. pressure limit was the desire, I think, of the Board of Boiler Rules in Massachusetts at that time. The only reason that they left their pressure at the 25 lb. limit was, I think, due to public opinion. I believe a number of hearings were held on this question by that Board back in the years of 1909, 1910, and 1911. But, when Ohio came to put a code into effect in that state they took advantage of the desires and opinions of the members of the Massachusetts board and made their limit of pressure 15 lb.

When the A. S. M. E. Boiler Code Committee went into that question they found that the 15 lb. rule had a good deal of reason back of it, and that limit was adopted after a good deal of thought and argument. There was quite a strong argument from some directions that the pressure limit of the boiler should be kept just as near atmosphere as possible, but after much discussion, prior to the time when Mr. May, Mr. McNair and Mr. Reed (of H. B. Smith & Co.) came into consultation with us, that pressure was finally decided upon as 15 lb.

One of the conditions that brought this about that may be of interest at this time was the legal side of the question—the enforcement of the Code by the State. The Board in a particular State must establish a line of demarcation, and it is the uniform practice, as you may all know, to enforce inspection of boilers of above that limiting pressure, and not to enforce inspection on boilers running below that pressure. It was the desire on everybody's part, I think, to keep the inspection requirement out of the heating class, or at least, as much so as possible; and it was the general desire of those that were interested in the legal side of the question to hold this pressure at such a point that there would not be any tendency for influence from certain interests to establish inspection laws for the low pressure or heating boiler side of the question. It was felt that anything leading in the direction of compulsory inspection of low-pressure equipment would work a greater hardship upon the industry than would the limitation of the maximum allowable working pressure to 15 lb.

Later on, when these hearings that are referred to in this paper were taken up, the representatives of the National Association of Boiler and Radiator Manufacturers came in, of which Mr. R. D. Reed of Westfield, Mass., is now the permanent representative on

the Boiler Code Committee, and they did splendid work. Their main work was establishing this line of demarcation between the power and heating classes of boilers. Mr. May is correct in saying that the argument concerning the pressure did not come up at that time, but it had been previously established and very definitely decided upon as far as the early members of the committee were concerned at the 15 lb. limit.

As to the question of having a change in this 15 lb. limit considered, there is an opportunity for Mr. Cassell, or anybody else who is interested, to bring the matter up before the Boiler Code Committee of The American Society of Mechanical Engineers for reconsideration. As stated in this paper, that Committee has been continued as a Committee to hear these questions, to receive these inquiries or complaints, and anything presented along that line in written form will be received as a Case and the Committee will act upon it in their next monthly meeting and a reply will be given. Up to the present time, 88 Cases have been considered, and the interpretations that have been rendered in practically all of these, have been published in the Journal of The American Society of Mechanical Engineers, and can be obtained, if desired, in reprint form upon application to the Secretary.

To answer Mr. Mayer, I will say the copies of the Code may be obtained from Secretary C. W. Rice of The American Society of Mechanical Engineers, at the regular price of 80 cents per copy. Our Society, as a sister organization, has access to those copies, however, at member's rates, 40 cents a copy. If you wish to apply through the headquarters, we can supply you with copies at the member's rate, and I would be glad to have any member of the Society who is desirous of obtaining a copy of the Code, take advantage of this privilege.

# In Memoriam

| | Joined the Society | Died |
|---|---|---|
| P. C. Doherty, Poughkeepsie, N. Y.... | 1907 | June 23, 1916 |
| W. A. Gates, Oklahoma City, Okla.... | 1912 | 1914 |
| John Jeffreys, London, England...... | 1899 | April 21, 1916 |
| Joseph McCusker, Portland, Ore...... | 1911 | August 1916 |
| W. S. Patterson, Appleton, Wis....... | 1905 | July 10, 1916 |
| Henry A. Volbracht, New York, N. Y. | 1914 | 1916 |
| H. R. Watson, New York, N. Y........ | 1915 | December 1915 |

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